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Economic Instruments for Reducing Ship Emissions in the European Union

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Executive Summary

This report, sponsored by the European Commission's DG Environment, analyses in detail four "economic instrument" approaches to reducing emissions from maritime sources in European sea areas. The report takes as its starting point earlier work undertaken by NERA to evaluate the feasibility of various economic instruments for reducing shipping emissions, expanding from this background to consider in much greater detail the design and implementation parameters that would be involved in adopting four promising approaches. The four approaches include credit-based emissions trading, benchmark-based emissions trading involving consortia of vessels, voluntary port dues differentiation based on environmental factors, and subsidies to promote clean shipping. The NERA study has been undertaken as part of a multi-part research project conducted by NERA with Entec UK, Ltd and IVL.

The report provides recommendations on various elements of these four approaches, dividing the parameters into two major categories:

- § *Design elements.* These are features that are specified initially and not expected to require additional review over time (although in practice some decisions could be revisited).
- § *Implementation elements.* These are features that require implementation on an ongoing basis, typically annually.

In developing these recommendations, we draw on the experience of a variety of existing programmes for both stationary and mobile marine sources. We also rely on the findings of the initiatives described below, including the Entec reports and the Demo Project.

Background

The significance of shipping to the EU is reflected in the number of vessels that travel through its waters, estimated to exceed 30,000 different vessels weighing in excess of 500 gross tonnes each year. The shipping industry's contribution to EU commerce is also reflected in its atmospheric emissions. Work undertaken by Entec (2002, updated as part of the current study programme in Entec 2005a) has estimated that in 2000, emissions from ships within 200 miles of EU coasts accounted for 2.3 million tonnes of SO₂ and 3.2 million tonnes of NO_x. The Commission has noted that, absent any new regulations on maritime vessels, shipping will be responsible for NO_x emissions that are on par with, and SO₂ emissions that are greater than, all land-based sources by 2020. This report focuses on SO₂ and NO_x emissions, although the mechanisms identified (suitably modified) also could be applied to other pollutants.

There are some common elements that any emissions policy for ships must include; among these are an appropriate legal basis, which is also related to an effective monitoring and enforcement regime. Any new policies to control emissions would have to be in conformity with international and EU law. The United Nations Convention on the Law of the Sea ("UNCLOS") sets out the basic legal framework that governs international shipping. The Convention gives some support for the control of air emissions (Article 212), but this is balanced against the right of ships to innocent passage without being subject to any charges, except for services received. Also relevant are current international environmental regulations, notably the International Maritime Organisation's ("IMO's") International

Convention on the Prevention of Pollution from Ships (“MARPOL”), which sets a global limit on fuel sulphur content, and also designates Sulphur Oxide Emission Control Areas (“SECAs”) in the North Sea and the Baltic Sea. MARPOL also sets NO_x emissions standards via the IMO “NO_x curve”. (The 2005 EU Sulphur Directive imposes additional requirements to limit fuel sulphur content in SECAs, imposes restrictions on passenger vessels throughout the EU, and requires ships at berth to use 0.1 percent sulphur fuel or better from 2010 onward. The policies considered here should be consistent with the existing legal framework for addressing emissions from shipping, although it is likely that certain details would need to be worked out for each one.

The four instruments also rely to varying degrees on the monitoring of emissions from ships. This is complicated by the fact that fuel consumption and emission factors are highly variable, depending on engine size, age, and load, on existing emission control technologies, on fuel composition, and on ambient conditions. In general, monitoring can be divided into periodic and continuous monitoring (periodic monitoring is cheaper but less accurate than continuous monitoring) and into monitoring of the fuel used or direct measurement of exhaust emissions (fuel-based is cheaper but less accurate than the monitoring of exhaust emissions). The appropriate trade-off between cost and accuracy is likely to depend on the instrument used, as requirements differ between different approaches. Additional considerations include the ability to keep track of emissions within a specific geographical area, which poses significant challenges without continuous monitoring. We assess various monitoring options that could be applied to different instruments.

Outline of the Study

The remainder of the report goes through in detail the design and implementation options for each of the instruments, touching on examples of policies that exist elsewhere. The design of instruments varies to some extent depending on the type of emissions, because of the regulatory context and the different monitoring alternatives. The penultimate chapter presents quantitative estimates of the costs and emissions benefits of different policies. We conclude with recommendations for the various design and implementation elements for two alternatives—benchmark trading for SO₂ and credit-based trading for NO_x—that appear to be particularly promising in the near term.

We emphasise that these conclusions and recommendations are tentative and preliminary for several reasons. First, many of the abatement technologies whose application we model are in very limited use, so the estimates of their costs and effectiveness are still relatively uncertain. Second, the analysis of necessity makes various simplifying assumptions about vessel activity and compliance strategies. Real-world conditions are likely to be more complicated. Finally, our characterisations and recommendations for the individual parameters of the various economic instruments in some cases have been chosen for illustrative purposes—setting different emissions baselines, for example, is likely to alter the impact of different policies.

Descriptions of the Four Economic Instruments

Credit-Based Trading Approach

Credit programmes provide tradable emissions “credits” to sources that voluntarily reduce emissions below their “business as usual” (“BAU”) levels. These credits can be traded and

counted toward compliance by other sources that would face high costs or other difficulties in meeting their own emissions requirements. Credits are generally created through an administrative process in which the credits must be pre-certified and approved before they can be traded. A credit-based programme would allow ship owners to reduce emissions and sell the emission reduction credits either to land-based sources assumed to be subject to a cap-and-trade programme or to the government if a subsidy programme were in effect. This approach would give ship owners experience in market-based mechanisms as well as considerable incentives for ship owners to participate.

There are several examples of credit-based emissions trading, particularly from stationary sources. The most prominent current examples may be the Kyoto Flexible Mechanisms, which include JI and CDM credits for greenhouse gas reductions. Another example is a pilot programme operated by the Californian South Coast Air Quality Management District (SCAQMD) since 2001, which allows emission reduction credits from marine sources to be used in the Regional Clean Air Incentives Markets (RECLAIM) trading programme. This programme has led to the modification of ships' engines, paid for by funds from stationary sources that are required to offset any emissions in excess of those allowed under RECLAIM.

The potential for cost savings of a credit-based programme is increased by including as many sources as possible a number of vehicle among those eligible to generate credits. It may be necessary to place some limits on eligibility because of concerns about additionality of emissions reductions, enforceability, or the cost of administering the programme. For example, concerns about administrative costs may lead to restrictions on ship size or type. Also, there may be a desire to allow only EU-based ships to qualify for credits (a similar provision is in force in the SCAQMD programme). However, such restrictions have to be balanced against the negative effects on cost-effectiveness; for example, approximately 40 percent of emissions in European coastal waters are from vessels travelling to or from ports outside Europe, and excluding these from a programme could undermine the usefulness of the programme. Similarly, it would be desirable to include a wide range of pollution control options. In general, more options are available to reduce NO_x emissions than SO₂ emissions.

A critical part of any credit-based programme is setting the emissions baseline. This can be among the most complex and contentious issues in designing a credit-based programme. A key concern in setting the baseline is to ensure "additionality" and to avoid giving ships "anyway credits," i.e., credits for reductions that would have been made in the absence of the programme. Requiring more detailed baseline information and monitoring procedures helps to ensure additionality, but this gain comes at the cost of additional administrative requirements that can substantially increase participation costs. Thus, there is a trade-off between avoiding "anyway credits" and increasing the cost savings from the use of credits; determining the appropriate balance is a key aspect of scheme design.

The technical details of establishing baselines can be complicated. Both the SCAQMD programme and the Demo project suggest possible approaches for NO_x, and another potential starting point is the IMO NO_x curve. For SO₂, the Marine Sulphur Directive could form at point of departure. In both cases, the precise formula for calculating credits needs to be developed with care, but the most appropriate baseline is a *relative* baseline (i.e., an emissions *rate* for each ship—otherwise ships could "reduce" their emissions simply by shifting activity outside the EU, with no real reductions in emissions.). It may also be appropriate to incorporate into the baseline some additional emissions reductions beyond "BAU" to reduce the possibility of giving credit for "anyway tonnes"

One of the advantages of a credit-based approach is that it would be entirely voluntary and thus would be unlikely to face much challenge with respect to international law. However, it is presumed that demand for credits would be generated by land-based emissions trading programmes, which may require modification of at least two European Directives—the Large Combustion Plant Directive (“LCPD”) and the Integrated Pollution Prevention and Control (“IPPC”) Directive. In the absence of a land-based trading programme, a credit-based approach could also be implemented via a government subsidy programme, whereby government simply purchased credits generated by ships.

A credit-based programme also would require the development reliable monitoring, reporting, and verification mechanisms. The complexity of these will vary with scheme scope, but likely parameters to be monitored include ship location, emissions factor, activity level, and energy consumption. As discussed above, there is a general trade-off between cost and precision of monitoring, and a range of technologies are available at varying expenditure to ship owners. A similar trade-off exists for administrative costs, as more detailed reporting requirements may help reach programme goals but are likely to result in more burdensome administration.

Consortium Benchmarking

In the approach considered here, vessels would have the option of joining a “consortium” that would voluntarily commit to achieving an average emissions rate, known as the benchmark. The specific proposal we consider allows for this programme to be voluntary, i.e., ships could form consortia and trade among themselves to achieve the average rate (which would be below the “BAU regulatory case” to account for the cost savings that flexibility would provide and avoid environmental backsliding). In contrast to a credit-based approach, there is no need to establish and certify a baseline emissions rate in the case of benchmarking, because the benchmark rate effectively serves as the baseline.

Existing experience with benchmarking includes the fuel economy standards for automobiles and mobile source averaging, banking and trading (“ABT”) programmes. In addition, the California Air Resources Board has proposed a scheme for reducing ship fleets’ NO_x and PM emissions by 50 percent (for frequent visitors to Californian ports). A pilot programme simulating the activity of a consortium has also been proposed by a group of European stakeholders.

Participation in a consortium would be entirely voluntary—the alternative would be for a vessel to comply directly with whatever existing regulation applied. As with credit-based trading programmes, there are a number of different ways that participation in a consortium might be limited. An important difference from the credit-based approach is that much of the administration of participation and reporting would be handled by the consortium itself, and this may put an effective limit to participation in practice: if appropriate penalties are in place, all consortium members have an interest in ensuring that consortium members abide by the rules, and consortia may have relatively strict requirements for membership.

Setting the benchmark emissions rate is a key component of programme design, corresponding to the determination of a baseline in a credit-based programme. Benchmark rates based on inputs (e.g. emissions per unit fuel) are the easiest to define, but output-based benchmarks (e.g. emissions per unit engine energy output, transport service rendered, etc.) may offer better incentives for a wider range of abatement measures. As in the case of credit-

based programmes, the IMO NO_x curve is a potential starting point for a NO_x emissions benchmark, while the Sulphur Directive could be a point of departure for SO₂ benchmark rates. Consortia can be differentiated by region, e.g., by restricting trade between regions, or by establishing “exchange rates” to reflect the relative damage of emissions in one area compared to emissions in another.

The consortium approach requires some existing mandatory regulation to offer incentives for trading consortia to form. This means that the relevant regulator needs to have jurisdiction over consortium members, including the ability to fine non-compliant vessels. In addition, consortium members would need to sign up to a binding agreement both with each other and with government authorities that would commit them to achieve a collective emissions rate and individually to discharge their responsibilities to pay into the consortium if their emission levels exceeded that level. This includes ways of handling surplus or deficits in agreed emissions, and deterrents to avoid breaches of agreements. External auditing is likely to be required for this purpose. Finally, consortium members would need to determine the rules governing entry and exit from a consortium.

The monitoring, reporting and verification of emissions would be by each ship owner to government, but also by the consortium as a whole to be sure that emissions from the consortium did not exceed the emissions permissible. One potential problem unique to the benchmarking approach is that individual members in fact are allowed to exceed what would otherwise be allowable emissions limits—provided these extra emissions ultimately are offset within the consortium. Thus some enforcement techniques, notably surprise inspections, may not be able to identify violations without additional cross-checking of consortium and vessel records. This may mean that other monitoring techniques need to be applied with more rigour than is required in some other types of programme.

Environmentally Differentiated Charges

The third approach considered involves the differentiation of port dues or other infrastructure-related charges along environmental criteria. The initial NERA report recommended that voluntary port dues differentiation be considered in more detail because much of the existing infrastructure for collecting dues is in place—ships already are subject to various charges for use of port facilities. Differentiated charges would involve basing dues in part on vessel air emissions, thus providing a financial incentive for low-emitting operation. The scheme considered here is based on the voluntary participation of ports, although we also discuss a more mandatory approach based on infrastructure charging (which would be more difficult to implement).

Dues differentiation has been applied in Sweden since 1998—both at the port level and for the use of Swedish fairways. The Swedish scheme appears to have been successful, but it is difficult to determine how much of this should be attributed to the voluntary port-based component, and how much to the mandatory fairways component. Other existing or previous programmes include ones in the Finnish port of Mariehamn, a discontinued pilot programme at the German port of Hamburg, the Green Award system providing a clean shipping certification to vessels that meet certain environmental guidelines, and one initiative in the US state of Alaska.

Important design parameters for differentiated dues schemes include the vessels eligible (e.g., passenger vs. cargo ships), the pollutants covered, and the qualifying control measures.

These relevant factors generally are summarised in an environmental index indicating the charges applicable to each vessel. In general terms, the index is likely to include a measure of emissions intensity (e.g., direct emissions rates, technology standards, or operational measures such as speed reductions), and a scaling factor linked to vessel characteristics (e.g., engine size or effect, vessel class, or ship size). Indices that are more differentiated (e.g. by vessel type) can reduce opportunities for free-riding. In general, providing incentives for as many different control measures as possible would give better cost-effectiveness. The full report provides considerable detail on different options for index design.

An advantage of the voluntary approach is that the administrative and institutional costs are relatively low. Indeed, existing port dues typically vary with parameters such as vessel class and size, the type of port, and the frequency of visit. The main additional requirement for the implementation of environmental differentiation is the creation of a regime for certification, monitoring, and verification of ships' emissions. Public authorities can help encourage the emergence of voluntary schemes by assisting in index designs that are relevant for the specific environmental concerns and in developing monitoring and enforcement regimes.

To reduce emissions successfully, any instrument must provide an adequate level of incentive for ship operators to undertake control measures. One important potential obstacle for voluntary dues differentiation is that port dues may not be high enough to provide sufficient incentives, even with substantial differentiation—particularly if only a small number of ports adopt differentiated dues structures. Moreover, many dues are not under the direct control of the port authority but are charged by third-party contractors. The extent of the incentive also depends on the type of ship and port (dues constitute a greater proportion of costs for certain vessel types than for others). Overall, differentiation of port dues on its own is unlikely to be sufficient to effect large-scale emissions reductions, and thus are likely to require complementary policies.

There are some measures that ports can take to ensure that the incentive provided is as high as possible. Notably, the level of incentive faced by the ship operator generally depends not on the actions by any one individual port, but on the dues structures of *all* of the ports it visits. Coordinated introduction of differentiation in several ports therefore would help make differentiation more effective. In addition, many control measures require up-front investment expenditure, and it would be important to provide operators with certainty that these would be offset by future savings. The effective incentive provided also would depend on the elimination of “free-riders”, i.e., avoiding rewards to ships that would have been low emitters anyway.

The viability of a dues differentiation scheme, like that of any voluntary scheme, requires that participants are not adversely effected by instituting environmental differentiation of dues. In theory, revenue neutrality could be achieved by keeping average dues constant, thus raising dues for high polluters while lowering them for cleaner ships. In practice, however, port operators have expressed doubt that this would be viable. Ports increasingly operate in a deregulated and competitive market and raising charges for some classes on ships may not be commercially feasible. Moreover, dues frequently are specially negotiated on a bilateral basis. Where prices are not set according to a fixed fee schedule it is hard to ascertain whether they include any differentiation. Ship operators therefore would have little certainty to recoup expenditure on control measures, and may also find it difficult to verify whether their dues are smaller than they otherwise would have been. These two features underline the difficulty of voluntary dues differentiation in a competitive environment. Although

coordination by ports could alleviate some of these concerns, it is difficult to see how this could be done without raising concerns about potential anti-competitive behaviour.

In sum, the main obstacles to a programme of voluntary port dues differentiation are to provide an adequate level of incentive, alleviating ports' competitive concerns, and reconciling differentiation with specially negotiated charges. Swedish experience suggests that when combined with a centrally determined mandatory charging programme, these problems may be surmountable. However, in many cases a voluntary system would not likely be viable, and other approaches to emissions reductions may therefore be required.

Environmental Subsidy Approach

Environmental subsidies involve financial support by the government of environmentally desirable activities. The support can come in the form of grants, low-interest loans, favourable tax treatment, tendering systems, and other financial assistance for products with desirable environmental characteristics.

Subsidies could be used to supplement other policy options. One example of this was a program in Sweden until 2002 to pay for part of the cost of installing SCR or HAM catalytic equipment, coinciding with the introduction of environmentally differentiated infrastructure charging. Another example was the Port of Hamburg, which for a limited period offered publicly funded discounts to port dues to ships fulfilling certain emissions criteria. In both these cases, subsidies were used as supplementary measures to other emissions reduction efforts.

An alternative approach is to use a stand-alone subsidy programme, aiming to provide independent incentive to reduce emissions. A potential example or model is the Californian Air Quality Investment Programme (AQIP). This programme is similar to the credit-based approach, but instead of using a market for credits the regulator purchases certified emissions reductions directly.

One way to provide such (supplementary) subsidies would be to incorporate environmental criteria into current support programmes, notably subsidies for ship-building. Several such programmes operate within the European Union, and current rules authorise European governments to provide a subsidy of up to 14 percent of the contract value of ships in "protected market segments", as long as the mechanism does not distort competition among EU shipyards. Making some of these subsidies contingent on environmental performance (such as a given emissions rate for ships built) could provide an effective incentive for emissions reductions. Other potential programmes that could be used for subsidies include EU-wide initiatives such as the "Marco Polo" programme to relieve congestion on European motorways, or the closely linked "Motorways of the Sea" programme, both of which could make support contingent on emissions reductions.

The drawback of incorporating (additional) environmental criteria into pre-existing support mechanisms is that it reduces the net gain to the shipbuilder or operator, as costs likely would increase without necessarily increasing the total support offered. This therefore could compromise the original objectives of such programmes.

One important design parameter for direct subsidy programmes is vessel eligibility. The provision of subsidies to non-EU ships is unlikely to be politically acceptable, but many ships

plying EU waters belong to this category, so limiting subsidies to EU vessels could reduce environmental benefits. As with other programmes, the ship type and location and pollutants covered also would have to be determined. The monitoring and verification costs of subsidy programmes differ significantly between different subsidy approaches, and are low in the case of one-off equipment installation / or retrofit but may be high in the case of stand-alone programmes based on quantified emissions reductions. Finally, and importantly, a subsidy programme also would have to determine an appropriate source of revenue, which may have to be substantial, in particular in the case of a stand-alone subsidy programme.

Experience from programmes elsewhere suggests that the development of stand-alone subsidy programmes is complex, a disadvantage compared to supplementary programmes. This is both because the level of funds provided would be higher, and because simple rules are unlikely to provide cost-effective independent incentives for emissions reductions. In both cases, safeguarding the cost-effectiveness of the scheme would entail distinguishing between cases where subsidies provide incentives for *additional* emissions reductions, and ones where they simply lower the cost to shipbuilders or operators of complying with environmental regulation.

In sum, subsidies typically have not used as stand-alone measures to achieve emissions reductions, both because of the amount of funds required and because they typically are complex and administratively burdensome (and therefore expensive). All subsidy programmes entail a trade-off between the complexity required to safeguard the cost-effectiveness of the control activities undertaken and the associated administrative cost. Also, there is a potential trade-off between avoiding financing reductions that would anyway have taken place (“anyway tonnes”) and making requirements so stringent that uptake is too limited for the programme to have an impact. For all these reasons, subsidies should probably be considered financing mechanisms that operate as adjuncts to mandatory emission control programmes rather than stand-alone emission reduction programmes.

Emissions Impacts and Costs

We use data developed by Entec (2005a-e) to characterise the emissions benefits and relative costs of applying different policy alternatives to European shipping, taking into account the costs of the various SO₂ and NO_x control technologies that might be employed. Developing estimates of the likely effects of these two approaches requires many assumptions about vessel activity and population, emissions rates, geographic distribution, and available abatement measures and costs. We emphasise that these results are illustrative rather than precise. Nevertheless, the empirical information provides insights on how specific programmes might be designed and what their environmental and economic effects might be. Full data on the assumptions are available in the main body of the report.

In each scenario considered we compare the cost of a “regulatory” approach to the cost of achieving the same overall environmental outcome using the more flexible economic instrument. The regulatory scenario in the case of NO_x corresponds to a requirement that all new ships reduce emissions 75 percent from BAU level and that older ships reduce emissions by 30 percent from BAU. For SO₂, the scenario corresponds to a requirement to use 0.5 percent sulphur fuel when operating inside SECA waters and 1.5 percent sulphur fuel when operating inside all other EU waters (or alternatively to apply an equivalent technical abatement option, e.g. scrubbing).

The policy options evaluated include a “full benchmark” scenario, in which all vessels participate in a benchmark trading scheme. This is contrasted with a voluntary consortium benchmark scheme, in which only 10 percent of vessels are assumed to participate. We also investigate credit trading programmes, both in the case of EU-wide participation and in a smaller region or sub-set of Member States corresponding to 10 percent of the fleet, and at different allowance prices. The main report describes each scenario in more detail.

Table ES-1 shows illustrative results for the cost-savings available for NO_x reductions using different policies. This indicates that the Full Benchmarking approach would yield 100 thousand tonnes more NO_x reductions than the Regulatory case, and would save more than €10 million compared to the Regulatory approach. Savings are smaller for the consortium benchmark approach, because fewer ships are assumed to participate.

Table ES-1. Emissions Impacts and Total Costs of Regulatory and Market-based NO_x Scenarios in All EU Sea Areas

	Units	BAU	Regulatory	Full Benchmark	Consortium Benchmark
Fleet Average NO _x Emissions Rate	g/kWh	13.32	10.16	9.82	10.12
Total NO _x Emissions	Million Tonnes	2.87	2.19	2.11	2.18
Total Cost of NO _x Controls	Million €	27	333	219	321
Average Cost Per Tonne Reduced	€/Tonne	N/A	489	291	467
Marginal Cost Per Tonne Reduced	€/Tonne	N/A	N/A	645	645
<i>Comparison to BAU</i>					
Additional NO _x Emissions Reductions	Million Tonnes	N/A	0.7	0.8	0.7
Additional NO _x Technology Costs	Million €	N/A	305	192	294

Source: NERA calculations

Table ES-2 shows the results for a credit-based approach to NO_x reductions. The results suggest that vessels could generate up to €202 million worth of savings in a regional credit trading scenario and up to €2.0 billion assuming EU-wide credit trading. (Note that the amount of savings from the benchmarking programmes and the credit programmes are not directly comparable, because the analysis of credit alternatives assumes that BAU policies include an existing land-based trading programme and associated costs, whereas the analysis of benchmarking programmes does not.)

Table ES-2. Implications of a NO_x Credit Programme under Different Credit Prices

	Units	Regional Credit Trading			Full Credit Trading		
		€500 / ton Credit	€1,000 / ton Credit	€1,500 / ton Credit	€500 / ton Credit	€1,000 / ton Credit	€1,500 / ton Credit
Fleet Average NO _x Emissions Rate	g/kWh	13.04	12.61	12.45	10.53	6.21	4.65
Total NO _x Emissions	Million Tonnes	2.81	2.71	2.68	2.27	1.34	1.00
Total NO _x Emissions Reduced	Million Tonnes	0.06	0.15	0.19	0.60	1.53	1.87
Total NO _x Credits Created	Million Tonnes	0.09	0.19	0.22	0.90	1.88	2.24
Total Value of NO _x Credits	Million €	45	188	336	449	1,878	3,358
Total Cost of NO _x Reductions	Million €	12	85	134	122	855	1,340
Net Savings	Million €	33	102	202	328	1,023	2,018

Source: NERA calculations.

Table ES-3 shows similar indicative results for SO₂ emissions. This indicates that the Full Benchmarking approach would yield almost 80 thousand extra tonnes of SO₂ reductions, while saving more than €500 million relative to the Regulatory approach.

Table ES-3. Emissions Impacts and Total Costs of Regulatory and Market-based SO₂ Scenarios

	Units	BAU	Regulatory	Full Benchmark	Consortium Benchmark
Fleet Average SO ₂ Emissions Rate	g/kWh	9.19	4.19	4.14	4.18
Total SO ₂ Emissions	Million Tonnes	1.98	0.90	0.81	0.89
Total Cost of SO ₂ Controls	Million €	506	2,036	1,452	1,978
Average Cost Per Tonne Reduced	€/Tonne	N/A	1,891	1,243	1,822
Marginal Cost Per Tonne Reduced	€/Tonne	N/A	N/A	1,244	1,244
<i>Comparison to BAU</i>					
Additional SO ₂ Emissions Reductions	Million Tonnes	N/A	1.08	1.17	1.09
Additional SO ₂ Technology Costs	Million €	N/A	1,530	946	1,472

Source: NERA calculations.

Finally, Table ES-4 shows the results for the credit-based approaches to SO₂ reductions. This indicates that €743 million could be saved if external SO₂ prices reached as high as €2,500/tonne and all vessel activity was considered eligible to offset reductions required by land-based sources. However, this price is higher than what might reasonably be expected under a cap-and-trade programme for SO₂.

Table ES-4. Implications of SO₂ Credit Programme under Different Credit Prices

	Units	Regional Credit Trading			Full Credit Trading		
		€500 / ton Credit	€1,500 / ton Credit	€2,500 / ton Credit	€500 / ton Credit	€1,500 / ton Credit	€2,500 / ton Credit
Fleet Average SO ₂ Emissions Rate	g/kWh	9.19	8.79	8.43	9.19	8.54	4.89
Total SO ₂ Emissions	Million Tonnes	1.98	1.89	1.82	1.98	1.86	1.07
Total SO ₂ Emissions Reduced	Million Tonnes	0.00	0.09	0.16	0.00	0.12	0.91
Total SO ₂ Credits Created	Million Tonnes	0.00	0.03	0.07	0.00	0.25	0.74
Total Value of SO ₂ Credits	Million €	0	38	185	0	381	1,852
Total Cost of SO ₂ Reductions	Million €	0	29	111	0	286	1,109
Net Savings	Million €	0	10	74	0	96	743

Source: NERA calculations.

Our analyses suggest that the specific nature of vessel activity—in particular, the time spent in European waters, SECAs, or other regions, can have a significant impact on which technologies will be most cost effective. Similarly, the nature of the policy requirements, and in particular the area over which emissions are considered to be of concern, can also dramatically alter the incentives for installing particular technologies because of differences in the opportunity to recover fixed costs.

For NO_x, our analysis suggests that the approaches based on economic instruments can achieve greater emissions reductions at substantially lower cost than less flexible regulatory requirements. These results apply both for the benchmarking trading scheme as well as for the credit-based approach. The gains are of course smaller if only some vessels would be eligible to take advantage of the flexible policies, as would be the case in the consortium trading approach or the regional credit programme. The credit-based approach seems particularly promising for NO_x, since it appears able to incentivise significant emissions reductions even in the absence of other regulatory requirements.

For SO₂ the flexible economic instruments also appear to generate comparable or slightly better environmental results at substantially lower cost compared to the less flexible alternative policies. Although the credit-based approach could offer significant incentives for operators to reduce emissions, the credit prices that would be required to do so may be higher than would be expected under a land-based trading scheme. This is in part due to the fact that existing regulations already require some emissions reductions, but may also simply reflect the relative cost of SO₂ reductions. For this reason it may be more feasible to achieve significant cuts in SO₂ via a benchmarking approach.

Conclusions Regarding the Relative Promise of the Four Instruments

The credit-based approach appears most promising for NO_x. There are a wide range of potential abatement measures to reduce NO_x emissions, and the cost of abatement appears low compared to the cost of land-based abatement. Baselines could be established on the basis of the IMO NO_x curve, and monitoring appears to be feasible. A credit-based approach for SO₂ could produce some cost-effective reductions, and the Marine Sulphur Directive does provide the basis for setting a baseline for determining credits, resolving one of the often contentious aspects of credit-based approaches. However, the allowance prices necessary to incentivise abatement—using either scrubbers or low sulphur fuel—are higher than the prices observed under existing trading programmes, and therefore for SO₂ a credit-based approach may not be as attractive.

A consortium benchmarking approach for NO_x would require a binding near term NO_x requirement for ships, which is unlikely to be forthcoming. NO_x benchmarking requirements could be based on the IMO NO_x curve, and could provide incentives to abate at substantially lower cost (approximately 45 percent savings) than a command and control alternative. The consortium benchmarking approach appears to offer advantages relative to a “command-and-control” requirement that all ships use low-sulphur fuels. This is primarily because abatement through sea water scrubbers is cheaper in many instances. Based on estimates of vessel activity, the cost under benchmarking could be 35 percent less than the cost of achieving the same emissions levels via the use of low-sulphur fuels alone. If other costs of fuel-switching were accounted for the cost savings are likely to be greater. Where the “regulatory” approach provides flexibility to use alternatives to low-sulphur fuel (i.e., sea water scrubbing), the regulatory approach could approximate the cost savings from benchmarking, but would still cost more. Monitoring protocols for NO_x would be more expensive than for SO₂.

The voluntary port dues programme appears less promising than the consortium benchmarking approach as a means of generating substantial reductions in either NO_x or SO₂ emissions from ships in the near term, unless a concerted effort were made to coordinate efforts among ports. Without co-ordination, the incentive provided by individual port action does not appear to be sufficient to induce substantial emissions reductions for most vessels. Also, responses from ports indicate that they are reluctant to differentiate their own dues for fear that it would place them at a disadvantage relative to competitors. In addition, competitive negotiation of dues may make it difficult for ship operators to verify the discount they receive upon reducing their emissions. In the longer-term the possibility of port coordination could be encouraged, however, through efforts to publicise dues differentiation and to assist in the development of standardised protocols. A more coordinated effort to apply infrastructure charges to a wider geographical range than individual ports—following on the apparent success of the Swedish fairways programme—may be a more promising alternative in the medium term.

The environmental subsidy approach—either as a stand-alone programme or an environmental modification of an existing subsidy—also appears somewhat less promising as a means of reducing NO_x or SO₂ emissions from ships. As noted above, the cost per tonne to incentivise “credit-based” SO₂ reductions from ships appears high, and thus the subsidy would have to be large to generate significant SO₂ reductions. As a point estimate, if the EC allocated approximately 10 percent of planned funds for Marco Polo II, or €10 million annually, to the most cost-effective projects to improve air quality, this could create incentives to reduce 16,000 tonnes of SO₂ or 224,000 tonnes of NO_x per year. Alternatively, this money could be used to fund specific measures, such as the construction of shore-side electricity berths. Securing funds would likely be difficult, and “redirecting” existing shipbuilding subsidies could risk undermining the original intent of these subsidies.

Overall, the policy instruments considered do appear to offer the potential for significant emissions reductions at lower cost than simple regulatory alternatives. We therefore recommend further development and implementation of such instruments. Detailed design recommendations are included in the full report.

1. Introduction and Background

In March 2004, NERA Economic Consulting (“NERA”) published a report on behalf of the European Commission (“the Commission”) evaluating the feasibility of a variety of economic instruments that could be used to control emissions from maritime sources (NERA 2004). The study investigated six broad types of instruments, providing comparisons of specific implementations of each type and assessing them against 13 environmental, efficiency, distributional, and institutional criteria. The study concluded that three of the specific approaches considered were worthy of further exploration.

The current report provides substantially greater analyses of the details that would be involved in designing and implementing these three approaches. We also evaluate the merits of a fourth approach—environmental subsidies. The work is sponsored by DG Environment of the European Commission and has been undertaken as part of a multi-part research project by Entec UK Ltd and IVL as well as NERA.

1.1. Objectives of This Study

As noted, this report expands on the conclusions of the NERA (2004) report, making recommendations for the development of four specific market-based approaches to promote low-emissions shipping in the EU. We provide recommendations on various elements of these approaches, dividing the parameters into two major categories:

- § Design elements. These are features that are specified initially and not expected to require additional review over time (although in practice some decisions could be revisited).
- § Implementation elements. These are features that require implementation on an ongoing basis, typically annually.

In developing these recommendations, we draw on the experience of a variety of existing programmes for both stationary and marine sources. We also rely on the findings of the initiatives described below, including the Entec reports and the Demo Project. The remainder of this chapter provides background on market based instruments, on other studies related to the use of market-based instruments to deal with emissions from ships, on the international legal context for measures to deal with shipping emissions, and on methods of monitoring shipping emissions, as well as a brief preview of the other chapters in the report.

1.2. Background on Market-Based Instruments and Emissions from Ships in the European Union

This report focuses on the use of market-based instruments to promote low emissions shipping. Market-based instruments, such as emissions trading, have taken on increasing importance in the control of emissions from all sectors. Beginning with the US Environmental Protection Agency’s (“EPA”) emissions trading programmes in the late 1970s, the US has embraced a variety of market-based instruments to control emissions. These initiatives include cap-and-trade programmes for electric generators as well as averaging programmes for mobile sources, including a programme for marine engines. The European Union (“EU”) has also recognised the importance of market-based approaches, initiating the EU Emissions Trading Scheme (“ETS”) in January 2005. The EU ETS sets an overall cap for EU CO₂ emissions and allows Member States to trade emissions reduction credits in order to meet the EU-wide obligations under the Kyoto Protocol. These

programmes have sought to take advantage of the benefits of market-based instruments, which give emissions sources the opportunity to find and employ the most cost-effective emissions control options. In addition to these market-based instruments, many Member States have instituted schemes that use other economic instruments—including environmental taxes, differentiated charges, or subsidies—to achieve environmental objectives.¹

This report focuses on the application of such economic instruments to the EU maritime sector. Shipping plays an increasingly important role in the EU, facilitating the movement of both people and goods within the EU and between the EU and other areas of the world. The significance of shipping to the EU is reflected in the number of vessels that travel through its waters, estimated to exceed 30,000 unique vessels weighing in excess of 500 gross tonnes each year. Of course, the shipping industry's contribution to EU commerce is also reflected in its atmospheric emissions. Work undertaken by Entec (2002, updated as part of the current study programme in Entec 2005a) has estimated that in 2000, emissions from ships within 200 miles of EU coasts accounted for approximately 2.0 million tonnes of SO₂ and approximately 2.8 million tonnes of NO_x.² Further, the Commission has noted that, in the absence of any new regulations on maritime vessels, shipping will be responsible for roughly equivalent NO_x emissions and even greater SO₂ emissions than all land-based sources by 2020. The absence of existing EU emissions regulations for ships also suggests that many cost-effective reductions may be available from the maritime sector.

1.3. Related Initiatives on Shipping Emissions in the European Union

As noted, this study draws on the findings of the NERA (2004) report, which explored numerous approaches to reducing shipping emissions. In addition to the NERA report, we also rely on the experience and findings from a number of other initiatives and studies that have explored issues related to emissions from the maritime sector. These include work by Entec and IVL, the Demo Project, work sponsored by SEAA, and a variety of initiatives sponsored at the level of individual Member States and ports. We discuss briefly each of these.

As part of the same European Commission initiative sponsoring the current study, Entec UK Ltd has undertaken two tasks focusing on shipping emissions. In the first (Entec 2005a), Entec investigates the preliminary assignment of ship emissions to Member States. In the second (Entec 2005b-e), Entec evaluates the costs and effectiveness of a variety of pollutant abatement technologies.

The Demo Project is a separate initiative being undertaken privately, on the initiative of the Swedish Shipowners Association, and directed by a team at PriceWaterhouseCoopers. The Demo Project explores a variety of issues related to the development of on-board monitoring techniques that would be involved in the implementation of a credit-based approach to reduce emissions from marine vessels. The Demo Project evaluates the feasibility of emissions monitoring and reporting techniques incorporating field tests of relevant technologies. Thus, the Demo Project report provides comprehensive descriptions of advanced, feasible

¹ For examples of several such approaches, see US EPA (2004).

² Throughout this report, we refer to sulphur dioxide ("SO₂"), the primary sulphur-based pollutant generated from maritime activity. Note that shipping emissions include other sulphur derivatives, including SO₃.

monitoring and reporting equipment and strategies. The plans proposed in the Demo Project incorporate continuous monitoring and verification of monitored data.

Shipping Emissions Abatement and Trading (“SEAA_T”), an industry advocacy group, has also been active in its support of approaches to reducing emissions from the maritime sector that involve economic instruments. Formed in 2002 by a consortium of shipping stakeholders and fuel suppliers, SEAA_T has advocated for flexibility in recent European regulations that govern the sulphur content of fuels. SEAA_T consultants have also authored several papers on the potential applicability of market-based instruments to the maritime sector. (Hirst 2002a,b and SEAA_T, *not dated*.)

On a smaller scale, many other European emissions initiatives have already examined or successfully targeted maritime emissions. Such initiatives include actions taken at individual ports and in the territorial waters of coastal nations. Several of these initiatives are discussed in later chapters, as they relate to the specific economic instruments considered here.

1.4. Legal Context for Regulation of the Maritime Sector

Any effective programme regulating maritime emissions will of course need to take account of the legal circumstances that govern maritime activity. Indeed, the international nature of shipping means that international regulations need to be accounted for in considering the legal context. To that end, the following section provides a very brief discussion of the existing international legal framework and its relevance for shipping. We then discuss one important EU regulation relevant for this report—the recently approved Directive governing the sulphur content of marine fuels.

1.4.1. UNCLOS

The United Nations Convention on the Law of the Sea (“UNCLOS”), formally codified in 1982, is the basic legal framework that governs international shipping. For the purposes of this study, it is important to consider the statutes pertaining to various bodies under UNCLOS. As noted in Davies et al. (BMT 2000), states operate in three capacities: as flag, port, and coastal states.

UNCLOS gives flag states the primary authority to impose environmental regulations (including those related to air emissions) on marine sources through their responsibility to enforce international laws. The roles of other jurisdictions—i.e., port and coastal states—“have traditionally been more limited” (BMT 2000). However, the language in UNCLOS suggests that non-flag states do have some authority to regulate marine emissions.

UNCLOS guarantees port states the right to “establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports or internal waters” (Article 211, paragraph 2). In addition, UNCLOS gives each coastal state the authority to control in-port emissions through its right to “exclude vessels from its ports or place conditions upon their entry” (BMT 2000).

Although coastal states have limited authority to regulate general pollution under UNCLOS, they appear to have greater power in the regulation of air emissions. Articles 212 and 222 of UNCLOS, which govern air emissions from marine vessels, are somewhat vague with respect to the jurisdictional limits of coastal states. Indeed, when it comes to air emissions, a state’s jurisdiction is defined with respect to infringement upon its airspace. Article 212 allows states to “adopt laws and regulations to prevent, reduce and control pollution of the marine

environment from or through the atmosphere, applicable to the air space under their sovereignty.”

While UNCLOS gives some jurisdiction to port and coastal states in the control of marine air emissions, the Convention professes a clear preference for international regulations wherever possible. IMO would manage any such international regulations.³ Though IMO is explicitly mentioned only once in UNCLOS (Article 2 of Annex VIII), UNCLOS frequently refers to the “competent international organisation” in connection with the adoption of international shipping safety and pollution standards; in most cases, this phrasing (i.e., “the competent international organisation”) has been interpreted to refer exclusively to IMO. IMO is generally responsible for the oversight of international shipping activity. In particular, IMO’s charter explicitly charges it with the oversight of safety and antipollution efforts in international shipping. Since its creation in 1948, IMO has established a variety of measures to enforce increased safety and reduced pollution from international shipping.

A major limitation affecting any jurisdictional authority relates to the right of innocent passage, which is also codified in UNCLOS. UNCLOS Part 2, Section 3 guarantees innocent right of passage for foreign-flag vessels in the territorial sea without being subject to any charges, except for services received. This restriction is clearly relevant to the control of emissions from shipping, since under a strict reading of this requirement, payments or charges related to reducing emissions from foreign-flag vessels would have to be embodied in a framework of providing services to those vessels. In addition, one aspect of the right of innocent passage, articulated in Article 21 of UNCLOS, precludes coastal states from enforcing any regulations that apply to the design, construction, manning or equipment of foreign vessels. This could be interpreted as restricting the ability of coastal states to require pollution abatement equipment or engine modifications on foreign vessels. One reason for considering market-based approaches to emissions regulations is that they offer a flexible means of complying with environmental regulations, and therefore may make it easier to promote the use of low-emissions technologies in certain sea areas, without impinging upon ships’ right of innocent passage.

1.4.2. International Regulations

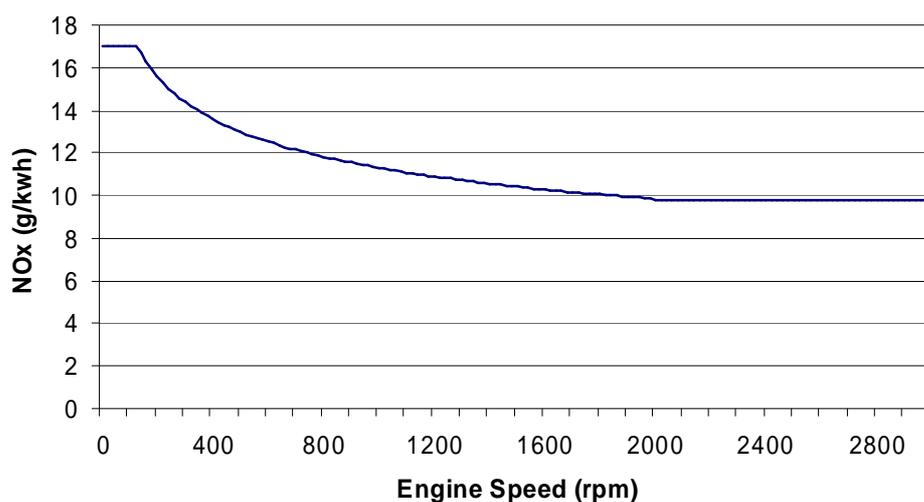
Although international regulation in other environmental areas is long standing, international efforts to reduce air emissions from ships are relatively new. International standards for the sulphur content of marine fuels and for NO_x emissions from new engines are contained in Annex VI to the International Convention on the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto, which was adopted in 1997. (This convention was developed by the International Maritime Organisation (“IMO”) and is known as MARPOL.) Annex VI sets a global limit on fuel sulphur content of 4.5 percent by weight, and designates two Sulphur Oxide Emission Control Areas (“SECAs”) in the North Sea and the Baltic Sea, where the maximum sulphur content of marine fuel should be 1.5 percent. Alternatively, abatement technologies yielding equivalent emission rates must be used. Annex VI entered into force on 19 May 2005.

Through the IMO Technical NO_x Code, Annex VI also sets NO_x emission standards, which are given by the curve in Figure 1. The IMO NO_x Curve sets the NO_x emission rate limit at 17 g/kWh for slow-speed engines, about 12 g/kWh for medium-speed engines, and 9.8

³ See IMO (2003).

g/kWh for high-speed engines. Though the NO_x Technical Code will not enter into force until May 2005, the requirements of the IMO NO_x Curve will apply retroactively to marine engines installed or converted in the year 2000 or later. In practice all engines built since 2000 already meet the IMO NO_x standards.

Figure 1. IMO NO_x Curve



Source: NERA calculations based on IMO information.

1.4.3. The EU Marine Sulphur Directive

In 2002, the European Commission presented a proposal to amend Directive 1999/32 as regards the sulphur content of marine fuels (henceforth, the “marine fuel sulphur directive”)

The European Parliament and Council finalised the marine fuel sulphur directive in April 2005 with a second reading agreement. At the time of writing, the directive had not yet been published in the EU Official Journal, but it had been formally signed and given the directive reference number 2005/33. The directive includes the following provisions:

§ Ships in IMO Sulphur Emission Control Areas must use 1.5 percent sulphur fuel or better – starting with the Baltic Sea in May 2006, then extending to the North Sea and Channel in autumn 2007.

§ All passenger vessels on regular services to or from Community ports must use 1.5 percent sulphur fuel or better from May 2006 onward.

§ Ships at berth in ports must use 0.1 percent sulphur fuel or better from 2010 onward.

These provisions would apply to all marine fuels and would replace the current regulations on marine gas oil, thereby establishing a similar regime for marine fuels as for heavy fuels and gas oils used by land-based sources, which are limited to 1.0 percent and 0.1 percent sulphur content, respectively. The Directive also allows ships to use other technical abatement technologies that achieve the same or greater levels of emission reductions, provided it can be demonstrated that these technologies do not adversely affect the marine environment. (The most often mentioned acceptable abatement technology is the desulphurisation of exhaust gases via “seawater scrubbing.”)

1.5. Emissions Monitoring

This section provides a brief overview of the monitoring options that would be available to work in conjunction with the economic instruments explored in this report.⁴ The success of each of the approaches depends on accurate measurements of emissions from ships. Put simply, a ship's emissions of a particular pollutant are the product of the ship's activity level (typically fuel consumption) and some emission factor per unit of fuel use or other activity. However, fuel consumption and emission factors are highly variable, depending on engine size, age, and load, on existing emission control technologies, on fuel composition, and on ambient conditions. If one could continually record the emission factors and fuel consumption rates, one could precisely measure a ship's emissions. Several monitoring options measure pollutant concentrations and fuel consumption rates, with varying degrees of accuracy. Inevitably, higher accuracy brings with it higher costs. The objective, then, is to balance complexity and cost with accuracy. An overly complex monitoring regime could become too costly and discourage shipowners from participating, while an overly simplified regime could jeopardise the approach's environmental objectives.

Here, we discuss, in general terms, the following five emissions monitoring approaches, ordered by increasing accuracy and cost:

1. Periodic Fuel-Based Estimates;
2. Continuous Fuel-Based Estimates;
3. Periodic Exhaust Monitoring;
4. Continuous Exhaust Monitoring; and
5. Continuous Exhaust and Fuel Monitoring.

As noted, this section provides only a very brief overview of these five approaches. Further details about specific monitoring strategies are presented in later chapters, where relevant.

A key concern for emissions monitoring strategies that target ships is the ability to isolate emissions within a specific geographical area. Since ships are mobile sources, they are free to enter or leave designated emission control regions. Thus, tracking the emissions of ships within a specific region would require the ability to keep track of when and where a vessel is responsible for emissions. Our discussion of the five emissions monitoring approaches addresses this requirement.

If a monitoring scheme is to be recognised and gain acceptance among many nations, it should conform to an internationally agreed-upon and harmonised standard—e.g., standards promulgated through IMO, the International Organisation for Standardisation (“ISO”), or the European Committee for Standardisation (“CEN”), and should rely on common, available technologies. In this chapter, and later chapters, the specific strategies and technologies that we discuss meet these two conditions. However, the options that we propose in this report may not be the only options available in future. For this reason, it is important that any regulation developed be flexible to adapt to technological developments. Also, the IMO's NO_x Technical Code requires that performance and calibration routines be practised on

⁴ The section draws on the internal report prepared by IVL (2005) for Entec as part of the current research programme.

monitoring equipment as quality assurance for measured data. Our discussion of monitoring strategies addresses this requirement.

1.5.1. Periodic Fuel-Based Estimates

This monitoring approach, the simplest, would involve periodically compiling fuel delivery receipts to obtain data on total fuel consumption by individual ships during each period. Combined with appropriate generic emission factors for different engine and fuel types, fuel consumption data would generate estimates of the total emissions from individual ships during each period. This strategy would require no costly monitoring equipment, and would allow for relatively simple data verification. Since emission factors can vary greatly, this approach carries substantial uncertainty—especially for estimates of NO_x emissions, since NO_x production depends on both ambient conditions and features of engine combustion. Moreover, it may be difficult to use this approach to measure accurately the emissions from vessels that frequently move in and out of relevant waters. It would therefore be difficult to use this method to identify emissions in a particular geographic area.

1.5.2. Continuous Fuel-Based Estimates

This approach would require continual on-board measurements of fuel consumption. Fuel consumption is difficult to measure directly on many vessels, so it may be necessary to monitor engine effect as a proxy for fuel consumption. Combined with appropriate generic emission factors for different engine and fuel types, these data would give on-board estimates of emissions from individual ships. This monitoring approach, since it incorporates continual fuel consumption measurements, could provide estimates of emissions in any particular geographical region. Data verification under this strategy would be relatively straightforward (since total fuel consumption figures are readily available), but onboard measurements of fuel consumption would require additional spending. As for the previous approach, this strategy would involve significant uncertainty, particularly for NO_x.

1.5.3. Periodic Exhaust Monitoring

This approach to monitoring would involve testing engine exhaust emissions periodically to obtain specific emission factors for individual ships during each period. Combined with data on fuel consumption (periodic or continual), these individual emission factors would give more accurate estimates of the total emissions from individual ships during each period than approaches based on a standard emissions factor. The periodic tests would necessitate somewhat expensive testing devices. Additionally, data verification would increase the cost of this strategy, as engine exhaust emissions would need to be double-checked occasionally by third parties. This strategy would carry uncertainties associated with the inability of testing conditions to replicate field conditions precisely. For example, test results may not give accurate emission factors for varying, or relatively high / low engine loads.

In addition, it is possible for shipowners to render periodic exhaust monitoring inaccurate to their advantage. Without continuous monitoring, shipowners could switch to higher sulphur fuel or “turn off” control technologies when their vessels are out of the range of shore.

1.5.4. Continuous Exhaust Monitoring

This strategy would require the installation of on-board exhaust monitoring devices on individual ships that would measure the amount of a particular pollutant in the exhaust. Combined with continual data on exhaust rates (which depend on fuel consumption rates),

these data would give estimates of emissions from individual ships during essentially any period. The estimates would have relatively low uncertainties, since they would be based on continual measurements of the actual exhaust from individual ships. However, the on-board exhaust monitoring devices would be quite costly, as would data verification (see the Annex).

1.5.5. Continuous Exhaust and Fuel Monitoring

This alternative would rely on the equipment used in engine manufacturers' testing laboratories. Such equipment would provide highly accurate data, with a high time resolution, on all emissions from individual ships. However, ships would not be practical locations for the equipment, and, if on-board installation were feasible, the cost of the equipment would be substantial.

1.6. Organisation of This Report

Chapters 2 through 5 of this report are organised by the four approaches being considered—the credit-based approach, consortium benchmarking, voluntary differentiated dues, and subsidies. For each of these approaches, we provide background on the instrument, a description of any real-world experience with similar approaches, and recommendations for the practical details of design and implementation. Chapter 6 provides a quantitative analysis of the economic and environmental performance of the different approaches. The report closes with conclusions in Chapter 7.

2. Credit-Based Approach

Credit programmes provide tradable “credits” to sources that voluntarily reduce emissions below their “business as usual” (“BAU”) levels. These credits can be traded and counted toward compliance by other sources that would face high costs or other difficulties in meeting their own emissions requirements. Credits are generally created through an administrative process in which the credits must be pre-certified and approved before they can be traded. A credit-based programme would allow ship owners to reduce emissions and sell the emission reduction credits either to land-based sources assumed to be subject to a cap-and-trade programme or to the government if a subsidy programme were in effect. This approach would give ship owners experience in market-based mechanisms as well as considerable incentives for ship owners to participate.

Section 2.1 describes prior experience with similar programmes. Section 2.2 describes the specifics of the design approach proposed here. Section 2.3 develops the implementation parameters that would be required for the design of a particular credit-based approach applied to shipping emissions in the EU.

2.1. Prior Experience with Credit-Based Programmes

This section provides overviews of three existing credit-based programmes. These examples provide important lessons for how a credit-based scheme might be structured in the EU. We first consider perhaps the most well-known credit-based approaches, which are linked to the trading provisions of the Kyoto Protocol. We then consider two credit-based approaches occurring within the marine sector.

2.1.1. Clean Development Mechanism and Joint Implementation

Credit-based programmes have been used to reduce the cost of meeting air emissions targets, particularly for stationary sources. The most prominent current programmes include two of the flexibility mechanisms provided for under the Kyoto Protocol—the Clean Development Mechanism (“CDM”) and Joint Implementation (“JI”). CDM allows for emissions reduction credit projects in developing countries, which do not have targets under the Protocol. JI allows trading of emissions reduction credits for projects in countries with quantitative emissions targets, which include developed countries and economies in transition.

The objectives of these programmes are to provide advantages both to Annex I countries, by allowing them to undertake less expensive reduction opportunities, and to developing countries, which would gain from the environmental and economic benefits of the CDM/JI projects. CDM and JI projects incorporate a wide variety of controls to reduce carbon dioxide emissions, ranging from energy efficiency improvements to the installation of renewable energy sources.

Several EU countries are actively pursuing CDM/JI credits. The largest programmes are the Dutch carbon funds—CERUPT and ERUPT. CERUPT has funded projects for over 18 megatonnes worth of CO₂e, while ERUPT recently completed its fifth round of funding for carbon-reduction projects. In the first several rounds of funding, ERUPT financed carbon reductions for an average price of around €5/tonne CO₂e, roughly a third of the current market price for CO₂ credits in the EU Emissions Trading Scheme. Although there are various steps involved in certifying credits as CDM/JI credits, these programmes promise to

provide the opportunity to reduce the overall cost of meeting the Kyoto targets for EU Member States.

CDM and JI projects relate to CO₂ and other greenhouse gas emissions rather than SO₂ and NO_x emissions. In addition, although they allow for the implementation of mobile source projects, the vast majority of potential CDM/JI projects have focused on reducing emissions from stationary sources. Thus, while they provide important background on the value of credit-based approaches and the general issues that arise, existing CDM/JI projects have not dealt with many of the specifics that could arise in a credit-based programme for marine sources of NO_x and SO₂ emissions.⁵

2.1.2. SCAQMD NO_x Marine Pilot Programme

A pilot programme developed recently in the Los Angeles Air Basin focuses specifically on NO_x emissions from marine vessels and provides significant insight into how such a programme might function in the EU. Adopted by the South Coast Air Quality Management District (“the District” or “SCAQMD”) in 2001, the programme allows marine vessels to reduce emissions of NO_x through engine modifications and receive credits in the Regional Clean Air Incentives Market (“RECLAIM”).

The programme was originally designed as a four-year pilot (2001-2005) with an objective of taking advantage of inexpensive emissions reductions from ships and providing the District and local shipowners experience with mobile source credit programmes. Because the initiative has largely been successful, District personnel are considering an expansion of the programme into future years (Eckerle 2005).

Since its inception, the programme has had roughly 45 vessels participating, including mostly tug boats and fishing vessels. The vast majority of these vessels have had their engine adjustments subsidised by District funds obtained from stationary sources required to offset their emissions in excess of those allowed under RECLAIM. In addition to the vessels that have obtained funding through this mechanism, several independent companies have paid for engine repowering directly and then sold the credits in the RECLAIM market.

2.1.3. Norwegian VOC Programme for Offshore Crude Oil Loading

Under the international Geneva agreement and the UN Economic Commission for Europe Gothenburg Protocol, Norway is committed to reducing its VOC emissions. To achieve these reductions, Norway has focused its efforts on emissions from offshore crude oil loading, requiring offshore rigs to employ technologies that reduce VOC emissions by 78 percent.

The burden to reduce offshore loading emissions lies with the oil companies drilling on the Norwegian continental shelf, as they are the recipients of Norway’s loading permits. The most cost-effective manner of achieving these reductions, however, is not to make changes to the drilling platforms themselves but to adapt the shuttle tankers that service them. With this in mind, authorities have endorsed a flexible approach to achieving the required reductions. The system allows oil companies to count loadings to shuttle tankers with VOC reduction technologies as qualified loadings.

⁵ Carbon emissions from international transport are not covered under Kyoto. Nonetheless, some evidence suggests that there are operational measures available to reduce CO₂ emissions, and IMO is in the process of developing a carbon indexing scheme for ships (IMO 2000 and IMO Assembly Resolution A.963(23), adopted 5 December 2003).

To facilitate cost-effective reductions (in the form of loading permits), the oil and transport companies have set up a quota trading scheme. Under the plan, each oil rig receives a yearly quota of allowed loadings without VOC reduction technology. These quotas, based on annual production and loadings at the oil rigs, are tradable. Oil companies can then choose whether to perform a particular loading with VOC reduction technology (at an increased cost) or to use one of their allotted loadings without VOC reduction technology. The operators of tankers with VOC reduction technology receive payment from each platform that uses their services based upon the VOC reductions achieved. Given the importance of timing to offshore loading—efficient use needs to be made of loading tankers to minimise the number of separate trips and vessels required, while also ensuring that each platform offloads its production at optimal intervals—the flexibility provided by trading has proved critical in facilitating cost-effective abatement using a limited number of specially fitted tankers.

As Norway's regulations have become more stringent (i.e. the percentage of offshore loadings required to utilise VOC reduction technology has increased), the quotas have diminished. By 2006, Norwegian regulations will require that 95 percent of all offshore loadings on the continental shelf be performed using VOC reduction technology. Even with virtually all offshore loadings regulated, allowing reductions from shipping in lieu of oil rig reductions will continue to make the overall compliance cost lower, while maintaining the same environmental objectives.

2.2. Design Parameters for Credit Scheme to Reduce Ship Emissions

This section discusses the key elements that would be involved in designing a credit-based programme to reduce shipping emissions in the EU.

2.2.1. Determining Participation / Eligibility

One threshold issue for any credit-based programme—or any environmental regulation, for that matter—is the question of which sources will be covered. As noted above, a credit-based programme would be entirely voluntary. Thus, whether or not each ship participates will be determined entirely by the shipowner.

Although participation would be voluntary, it will be the responsibility of the regulator or relevant authority to determine which ships are eligible for the programme. There may be various reasons to restrict participation, including concerns about equity, additionality, enforceability, the viability of an emission reduction project, and the cost of administering the programme. From a cost-effectiveness standpoint, there is good reason to include as many types of ships as possible, although some attention may need to be given to the potentially higher administrative costs associated with the inclusion of foreign vessels, for example. Because including more vessels would allow more participants and thus more credits, the effect would be to lower the overall compliance cost for land-based sources.

In the following sections, we discuss three possible lines along which participation might be restricted: geographic/location requirements, ship size/type, and ship flag.

2.2.1.1. Geographical restrictions: Location of vessel activity

The programme might only allow ships that travel in certain waters or spend a certain proportion of their time in EU waters to participate. The basic rationale for restrictions of this kind would be logistical simplicity in light of the potential air quality effects of emissions from different locations. Monitoring or enforcing emissions reductions from ships that have

international routes could be administratively burdensome, and these burdens may not be justified if few emissions affected air quality in EU Member States.

To deal with this issue, the SCAQMD programme only allows “captive” marine vessels to participate. Captive marine vessels are defined as ships that operate exclusively within covered waters (i.e., within 25 nautical miles of the District’s shoreline).⁶ District officials described several reasons for limiting the programme to captive vessels. First, because the geographic area of Los Angeles is relatively small, ocean-going vessels emit only a minor proportion of their emissions in areas that are geographically relevant for the District’s air quality. District officials also expressed the concern that it would be nearly impossible to perform any inspections or enforcement if ocean-going ships were included. In addition, including only captive vessels provides a greater sense of certainty regarding the level of activity—and therefore reductions—to expect from participants. For all of these reasons, the District concluded that it was not sensible to include ocean-going vessels in its pilot programme (Sarkar 2005).

Of course, the major disadvantage of such an approach is that it excludes a significant source of maritime emissions. Because vessels travelling to or from ports outside Europe are responsible for approximately 40 percent of emissions in European coastal water (Entec 2002), geographic limitations of this sort would significantly limit the cost savings or emissions reductions that could be achieved.

Because the EU has a much larger geographical scale than the city of Los Angeles, the pollutants emitted in a significantly larger area are relevant for EU air quality. Thus, concerns that only a small proportion of emissions from ocean-going ships would be relevant for air quality are not nearly as significant for the EU. Of course, the programme would have to credit only a certain portion of emission reductions from ocean-going vessels (as discussed below). As a result, self-selection would prevent ships whose emissions were primarily irrelevant to EU air quality from participating. Of course, there could be administrative complications unique to ships with very wide geographic ranges. For example, tracking fuel consumption would likely be more complicated for ships that leave EU waters.

Unless the added administrative cost of including ships that travel outside of EU waters outweighs the benefits of including additional sources, it would be sensible to allow ships to participate regardless of their shipping routes or geographic breadth. Alternatively, if the scheme were designed somewhat more modestly at the outset, some geographic restrictions might be sensible—similar to the SCAQMD approach. As noted, because only a few Member States are currently implementing emissions trading to comply with the LCPD, it is conceivable that credit-based trading might only be adopted by certain—or even a single—Member State. If this were the case, some geographic restrictions would almost certainly be warranted as a means of focusing on relevant shipping emissions.

2.2.1.2. Restrictions on vessel size or type

The programme could also restrict participation to include only ships over a certain minimum size or ships of certain types (e.g., ferries but not oil tankers). Like geographic restrictions,

⁶ The only exception is for up to two maintenance trips per year, which are permitted to involve travel outside of covered waters.

any limits on ship size or type would have the practical effect of reducing the cost of administering the programme because there would be fewer participants.

For example, the SCAQMD programme places restrictions on ship size, although these restrictions actually place a *maximum* on the size of vessel that can be included, limiting participation to only crafts with US EPA Category I and II engines.⁷ These size limits stem from the fact that the programme is intended as a pilot; including smaller ships was viewed as a more modest undertaking, much like the decision to limit the programme's geographic scope.

In an EU programme, if any restrictions were placed on size, it would be more sensible to require vessels to be of a *minimum* size. One potential rationale for such restrictions would be if the administrative cost of dealing with very small sources outweighed the benefits and cost savings associated with having those ships participate.

One potential disadvantage of size restrictions stems from the great variety of types of ships that travel to different ports. Restrictions on the size of ships allowed to participate could mean that the vessel traffic at some ports is largely unaffected, while the traffic at others is affected substantially. Thus, only some areas within the EU could benefit from the environmental improvements of a credit programme if participation were restricted. Any restrictions on participation would also tend to discourage take-up and experimentation. For these reasons, limiting vessels on the basis of size probably is not sensible.⁸

2.2.1.3. Vessel flag

The authorities could choose to allow only ships flagged from certain countries (e.g., only EU countries) to participate in the programme. Restrictions of this sort could stem from concerns about equity—for example, in this case, a feeling that it would be unfair to allow foreign ships to benefit from an EU environmental programme. Similar arguments have been made in the context of CDM/JI projects. Another possible concern about including non-EU flagged ships would be that the EU would not have the legal authority to enforce programme rules on foreign ships. If foreign-flagged ships violated rules, levying penalties in response could also prove logistically, if not legally, difficult.

Because foreign-flagged ships are probably more likely to travel outside EU waters, many of the concerns discussed in the context of geographic flexibility would also apply here, including the possibility of high administrative costs. As noted above, the voluntary nature of the scheme will mean that only ships producing a significant quantity of emissions reductions will choose to participate. This self-selection should prevent sources from entering the programme whose benefits would not outweigh the added private administrative costs of including them, although public agencies may incur administrative costs.

Including foreign-flagged vessels would reduce the burden borne by land-based emitters and EU consumers. Depending on their respective levels of activity in EU waters, a credit programme could benefit significantly from allowing ships of all flags to participate.

⁷ US EPA classifications for Category I and II engines include all engines with a displacement up to 30 litres.

⁸ Self-selection may eliminate some vessels, particularly smaller ones, for which the private administrative burden is too great to justify participation.

2.2.2. Covered Pollutants and Incentivised Measures

An issue closely related to participation is the extent to which various control options and pollutants would be covered in the programme. For example, the SCAQMD programme specifically targets NO_x reductions attained through remanufactured or newly installed engines, which have lower NO_x emissions. The programme does not include SO₂ reductions or allow credit generation from the installation of NO_x control technologies (e.g., SCR or HAM)—the latter because the technologies were not available at the time the programme was conceived.

The following sections discuss the pollutants that would likely be covered and the NO_x and SO₂ control options that could be accounted for under a credit-based programme.

2.2.2.1. Covered pollutants

While a credit-based programme could be expanded to cover additional pollutants, the approach described here targets emissions of NO_x and SO₂. Where relevant, we make reference to the other pollutants that would be affected, notably PM and CO₂. For PM in particular, it is important to note that both NO_x and SO₂ are sources of secondary particulates formed in the atmosphere, and thus reductions in NO_x and SO₂ are likely to lead to PM reductions.

2.2.2.2. Covered SO₂ control options

Ship owners have three major options to reduce emissions of SO₂: switch fuels, install a scrubber⁹, or improve fuel efficiency. The baseline and monitoring regimes described below would create incentives for ship owners to adopt either fuel switching or scrubber installation. But because this programme would have a “relative” baseline (as discussed below), changes to fuel efficiency probably would not be incentivised. To incentivise fuel efficiency improvements would require an explicit change to the monitoring regime to record some measure of output (e.g. tonne-kilometre transported), which could make the calculation of credits more difficult.

2.2.2.3. Covered NO_x control options

Ship owners may have more options available to reduce NO_x emissions than SO₂ emissions, including installing selective catalytic reduction (“SCR”), direct water injection (“DWI”) or humid air motor (“HAM”) technologies, making internal engine modifications, or installing a new engine. Since all of these approaches would affect emissions rates, the programme would capture their benefits and thus credit ship owners with the reductions generated from all of these abatement options. As with SO₂, many efficiency measures would not be specifically incentivised by the approach unless alternative activity measures were used.

2.2.3. Setting the Baseline

In designing a credit-based programme, by far the most critical issue is determining the appropriate baseline level of emissions. The baseline is critical because it determines the level

⁹ A scrubber is an emissions control technology commonly termed flue gas desulphurization or “FGD” that can be installed to reduce SO₂ and other emissions. The early applications were for land-based sources, but “sea-water scrubbing” is increasingly viewed as a possibility in the shipping sector. .

below which ships receive credits. As noted in the NERA (2004) report, setting the baseline emissions level can be among the most complex and contentious issues in designing a credit-based programme. Some discussion of these issues is provided in the results of the Demo project, where various baseline alternatives are considered and tested. A key concern in setting the baseline is to avoid giving ships “anyway credits,” i.e., credits for reductions that would have been made in the absence of the programme. That is, it is important to ensure that credits are “additional.” Non-additional credits can compromise emission reduction objectives as well as the credibility of the approach. More detailed baseline and monitoring procedures can reduce the likelihood of anyway credits. However, experience indicates that these additional administrative requirements can substantially increase participation costs. This reduces the likelihood that entities will participate and thereby generates cost savings. Thus, there is a trade-off between avoiding “anyway credits” and increasing the cost savings from the use of credits (see Harrison et al. 2000).

In determining the appropriate baseline, there are two threshold issues that must be addressed. The first issue is whether to set an *absolute* or a *relative* baseline. For some land-based programmes, authorities have set baselines according to absolute emissions levels for emitters. For example, a particular industrial facility might have baseline emissions of 1,000 tonnes of NO_x annually, and if total emissions are below that level for the year, the emitter receives credits, which can be sold in the emissions trading market.

As noted in the NERA (2004) report, however, for shipping it would be more sensible to set *relative* baselines for individual emitters—that is, to set a baseline emissions *rate* for each ship. If an absolute baseline were provided, an individual ship could “reduce” its emissions—and thus generate more credits—by shifting European traffic to other ships, generating credits but no real emissions reductions. With a relative baseline, the ship would have to travel to obtain credits. Ships would thus receive credits equal to the difference between their actual emissions rate and their baseline emissions rate, multiplied by some measure of their activity.

The second threshold issue for a credit-based programme is whether to have a ship-specific baseline or a general baseline for all ships. The decision about which approach to take represents a trade-off between cost/complexity and accuracy. Generally speaking, a ship-specific baseline is more expensive to estimate but also more accurate and less likely to result in “anyway” credits. A generic baseline, on the other hand, has the advantage of being relatively straightforward administratively, since there is no need for the authority to explore the specifics of each ship. It is not clear which of these measures is more likely to avoid the problem of “anyway credits”—ship-specific approaches run the risk of over-crediting vessels that replace older engines with more efficient ones if they would have replaced them anyway, but generic approaches can also fail to take into account vessel-specific circumstances and award anyway credits.

Because of the complexity of setting the baseline, it is sensible to determine an appropriate baseline procedure separately for each pollutant. The following sections discuss the various baseline procedures for SO₂ and NO_x. The subsequent section on the calculation of credits discusses the specific recommendations.

2.2.3.1. SO₂ baseline

SO₂ is formed when the sulphur in a ship’s fuel reacts with oxygen during combustion. Thus, a vessel’s SO₂ emissions have little to do with the specifics of a ship’s design or engine configuration. Unless the ship has a scrubber installed, its emissions of SO₂ can be easily

estimated as a function of two variables: the sulphur content of its fuel and the amount of fuel burned. Thus, there is probably little need to measure the baseline SO₂ emissions from each ship separately. Rather, a common framework could be used for all ships.

The fuel limits in the Marine Fuel Sulphur Directive could be used to generate baseline requirements, since ships would be subject to these regulations whether or not the credit scheme is introduced. Because of the simple relationship between fuel type and emissions levels, these fuel standards could easily be translated into a baseline emissions level per tonne of fuel burned. If the programme were designed to have a geographic scope that extended beyond areas where the Directive on sulphur content of fuel limits applied (i.e., Exclusive Economic Zones and territorial waters), the limits in territorial waters could serve as the baseline for these areas.

2.2.3.2. NO_x baseline

The majority of NO_x from marine diesel engines is formed when nitrogen *in the air* reacts with oxygen during combustion. As a result, in contrast to SO₂ formation, NO_x formation is sensitive to a variety of variables, including engine design and efficiency, fuel type, air temperature, humidity, and atmospheric pressure. The result is that NO_x emissions from ships are far more complicated than SO₂ emissions and thus determining baseline emissions for NO_x is far more complicated. Because of this complexity, it is less clear whether a general or ship-specific baseline should be developed.

The SCAQMD programme takes a ship-specific approach to setting baseline emissions rates for NO_x. In order to receive credits in the programme, ships must install a new or remanufactured engine. Prior to the installation of the new engine, the District requires that the ship submit to NO_x emissions testing with the old engine. This emissions rate then serves as the baseline, against which any reductions are credited. As described below, this emission rate is then multiplied by an activity level to determine the *total* baseline emissions. Baseline testing procedures must also meet the following criteria:

- § The baseline emissions rate must be reported in grams per brake horsepower-hour (g/bhp-hr) or grams per kWh (g/kWh).
- § The engine must be tested using either (1) the International Organization for Standardization's protocol 8178-3 for the measurement of exhaust gas smoke characteristics for internal combustion engines or (2) the California Air Resource Board-approved in-situ source testing.
- § The baseline emissions rate may be no more than 19.8 g/bhp-hr (26.6 g/kWh).
- § Engine injection timing should be set to original equipment manufacturer's recommended specifications if available and applicable; otherwise, according to normal operating parameters.

An alternative ship-specific approach is suggested by the Demo project. For certain abatement approaches, it would be possible to monitor the baseline emissions and emission reduction continuously. For technologies like SCR, which require urea as a reducing agent to achieve emissions reductions, emissions could be tested continuously both before and after the urea is injected. Such an approach would be the most accurate baseline technique and would probably do the most to avoid "anyway" credits. Of course, this approach is limited in

that it is likely to be more expensive than others and would not work for some control options (e.g., engine efficiency upgrades). Thus, if this approach were selected, a separate approach would need to be designed for other controls.

As an alternative to a ship-specific baseline approach, it would be possible to establish a general baseline for all ships, as we recommend above for SO₂. Any general baseline for NO_x would almost certainly start with the current international standard for NO_x emissions rates for new vessels—the IMO NO_x Curve. The IMO NO_x Curve sets NO_x emissions rates limits (in g/kWh) for newly built or significantly retrofitted ships engines (after 1 January 2000). The IMO curve emissions rate limits vary based on rated engine speed, as discussed in the introduction.

The selection of a NO_x baseline is ultimately complicated by the wide variation in NO_x emission rates among current ships and the lack of any binding standards for existing marine engines. The sole NO_x standard for marine engines—the IMO NO_x Curve—applies only to new or substantially rebuilt engines. Nonetheless, this curve is the only standardizing metric available against which ships' NO_x emissions can be judged and thus probably represents the best choice as a starting point for a NO_x baseline.

Once the IMO NO_x Curve has been selected as the basis for determining the NO_x baseline, there may be further modifications to establish the baseline. As discussed in the previous NERA (2004) report, a more stringent curve could be developed to serve as the baseline.¹⁰ This would have the advantage of increasing the certainty that the credits being generated were indeed additional. Of course, it would also have the consequence of reducing the incentives to participate and thus lowering the number of participants. Ultimately, though, a slightly more stringent baseline would help to preserve the environmental integrity of the programme. It may also be desirable to make adjustments to the IMO NO_x Curve to account for varying ambient conditions.

2.2.4. Geographic and Temporal Differentiation

This section addresses two issues that have been important in the design of many emissions trading programmes—variation over geography and across time.

2.2.4.1. Geographic differentiation

Although most emissions trading programmes do not differentiate between covered emissions in different locations, concerns about the different effects of emissions from different locations have been raised.¹¹ For example, concern over the differential effects of pollutants emitted in different locations was raised during the development and early implementation years of the US Acid Rain Program. The basic concern was that “hot-spots” could develop in which pollutant concentrations and environmental damages were higher than in other regions. In the Acid Rain programme, some US states attempted to address this concern by placing restrictions on out-of-state trading. Empirical evidence suggests that in this case these

¹⁰ The NERA (2004) report identified an instrument referred to as the “Rigorous credit-based approach,” in which the emissions baseline was set somewhere below business as usual (“BAU”) emissions.

¹¹ The RECLAIM programme does differentiate emissions into two regions for trading purposes. See Harrison 2003.

concerns were misplaced, as emission reductions were actually greatest in the areas of greatest concern (Ellerman et al. 2000).¹²

This experience implies that geographic differentiation of emissions may be unnecessary, but geography is likely to be substantially more important for the shipping case than for land-based sources because many ships' routes include travel that is hundreds—or even thousands—of kilometres from the nearest coast. Since the environmental effects of a tonne of NO_x, SO₂, or PM emissions thousands of kilometres from land is clearly less significant than the effect of a tonne emitted in port, there is a need for some form of geographic differentiation, at least with respect to emissions that are included in the programme.¹³

Recognising this issue, the SCAQMD programme for marine credits allows only vessels travelling exclusively in the District's territorial waters to participate and generate credits. It does not, however, differentiate emissions within that area. As described above, this approach makes sense because ocean-going ships simply do not spend enough time in areas where their emissions will significantly impact Los Angeles's air quality. For a region the size of the EU, however, such an approach is unsuitable because emissions over a much broader area are relevant.

As the NERA (2004) report describes, the possible range in complexity of a scheme for geographic differentiation is wide. A simple scheme could limit credit generation only to certain regions (e.g. the Member States' Exclusive Economic Zones ("EEZ") or the territorial seas), but not differentiate the value of credits generated within those areas. This approach would be similar to the SCAQMD approach without the restriction on participation. A more complicated approach would place weights on emissions in different areas. For example, emissions in SECAs could be weighted more heavily than emissions in other areas.

Existing research suggests that NO_x emissions are likely to have effects over very broad geographic areas because of their contribution to secondary particulate matter (PM_{2.5}) and ozone. The effects from SO₂ can be more localised, while the environmental impacts from deposition tend to occur over a much broader geographic area (Murlis 2003).

Existing scientific evidence and experience with emissions trading programmes both suggest that emissions from both SO₂ and NO_x are relevant over broad geographic areas, particularly taking into account their contribution to the formation of secondary PM (sulphate and nitrate particles). Further, the administrative costs of a complicated system of geographic weights could be high. In the absence of scientific results suggesting that emissions a certain distance from the coast should be discounted, it may be easiest to avoid a complicated scheme of geographic weights at this stage—either for SO₂ or NO_x. However, this is an area that merits further consideration as the relative impact of emissions at varying a distances from land becomes clearer.¹⁴

¹² Of course, this was an empirical question, and its resolution in the case of the Acid Rain Programme might not apply to shipping.

¹³ Note that this is not the case for CO₂ or other greenhouse gases; these emissions have the same environmental impact regardless of their location.

¹⁴ The requirement that by 2010 all vessels burn 0.1 percent sulphur fuel while in port in contrast to higher limits at sea suggests that emissions in port are considered the cause of greater harm than emissions at sea. The Commission is currently sponsoring a study exploring the benefits of emissions reduction policies for different geographical regions. Among other things, the study will consider the optimal extent of control areas for air quality policy. The distance from shore over which environmental programmes will apply is a particular focus of the study.

For all of these reasons, it seems sensible to develop a more simplified approach to geographic weighting—at least at the outset. This approach would only credit emissions reduced in the territorial seas but would weight all credits equally. If the cost of administering this relatively simple approach is manageable, a more complicated approach could be implemented in the future. Because this approach would still require tracking ships' movements, it would provide important experience with the complexities of administering and enforcing detailed geographic monitoring (which is discussed below).

2.2.4.2. Temporal differentiation

Issues to be resolved with regard to temporal differentiation include rules governing “banking” of credits and “sunsetting” of the award of credits.

2.2.4.2.1. Banking

In many emissions trading programmes, temporal flexibility has been provided by allowing participants to “bank” emissions—i.e., allowing participants to save credits for use or sale in future years. Restrictions on banking and borrowing can be imposed to ensure emissions targets are met in specific years, although less restrictive methods have been developed to guard against excessive emissions in a given year. Experience indicates that banking lowers the overall cost of compliance without negative environmental consequences. For a credit-based programme, the decision to allow or disallow banking would be made in the development of the relevant cap-and-trade programmes. Credits generated from marine sources would presumably conform to whatever regulations were established for allowances for land-based emitters in the programme.

2.2.4.2.2. Sunsetting

The SCAQMD programme includes a “sunset” clause that prohibits ships from generating credits after the middle of 2005. SCAQMD officials have indicated that this provision helps to guarantee additionality. Indeed, if business as usual (“BAU”) emissions levels are expected to change in future, this either needs to be reflected in the design of the programme, or a sunset clause needs to be included. For example, if the credit programme encouraged a shipowner to install a new engine five years earlier than the owner would have otherwise done, the ship would generate *additional* credits for five years. Yet, without a sunset clause or some provision in the regulation to adjust baselines over time, the shipowner might continue to receive credits indefinitely even though the new engine would have been installed *anyway* after five years.

If the general emissions baselines recommended here are used, then the sunsetting issue would come into play if emissions standards—either the Sulphur Directive or the IMO NO_x Curve—were tightened over time. To address this issue, a provision to deal with any changes in these requirements also should be explicitly incorporated into the regulation.

2.2.5. Calculation of Credits

2.2.5.1. SO₂ formula

The Marine Fuel Sulphur Directive sets separate limits on the sulphur fuel content permitted in ports, SECAs, and elsewhere in territorial waters; as noted, these limits would form the baseline emissions rates for the determination of SO₂ credits. Total baseline emissions could then be calculated in each of these distinct areas (as well as the rest of EU sea areas by

combining this information with data developed from continuous monitoring of activity levels and location.

As described below, we recommend that actual SO₂ emissions be monitored continuously and in conjunction with position monitoring. This will generate estimates of total *actual* SO₂ emissions in port, SECAs, and territorial waters. We would also expect monitoring to develop information on total emissions in the remainder of EU sea areas.

Using this information, the number of SO₂ credits can be calculated by simply subtracting total baseline emissions from total actual emissions. As suggested in NERA (2004), an environmental benefit could be ensured by applying an adjustment factor at the discretion of the Commission. For example, the SCAQMD applies a 90 percent factor to its credit generation scheme (for NO_x), retiring the remaining 10 percent of credits for the benefit of the environment. This is equivalent to setting the baseline below BAU, leading to greater environmental benefit than would arise from a land-based programme alone.

2.2.5.2. NO_x formula

Because of the chemical reaction that leads to NO_x formation, calculating the amount produced is substantially more complicated than it is for SO₂. Nonetheless, as with many of the programme parameters, the complexity of the approach taken can vary widely—from relatively simple to fairly complicated. The SCAQMD programme uses an approach to calculating NO_x credits based on the following formula:

$$\text{MSERC} = \frac{(EF_{\text{base}} - EF_{\text{opt}}) \times EC_{\text{opt}} \times AL \times 0.90}{454}, \text{ where}$$

MSERC = Mobile Source Emissions Reduction Credits (standard tonnes)

EF_{base} = Baseline emission factor (in g/kWh)

EF_{opt} = Optional (i.e., post-retrofit) emission factor (in g/kWh)

EC_{opt} = Energy consumption factor at the maximum rated speed for the replacement engine (in kWh /gallon)

AL = Activity level (in gallons of fuel consumed)

454 = Conversion factor from grams to pounds

0.90 = Discount for the benefit of the environment

This formula reflects the District's periodic approach to measuring emissions rates by comparing the baseline and post-retrofit emissions rates. Another notable aspect of the formula is that the activity level is measured in gallons of fuel consumed; fuel usage is then converted to energy (in kWh) by applying an energy consumption factor. In addition, as noted above, the formula applies an environmental discount factor to generate a 10 percent environmental benefit.

Perhaps the most accurate way of estimating NO_x credits would be to use an approach suggested in the Demo project. This approach, which is noted above, would involve continuously monitoring emissions of NO_x before and after the application of a control technology such as SCR. The difference in emissions levels would then be coupled with location data to determine when credits were being generated. Such an approach would

eliminate much of the uncertainty inherent in applying proxy emissions formulas to estimate emissions.

If the IMO NO_x curve or some derivative of it (for example, 10 percent below the curve) is selected to serve as the baseline, baseline emissions can be estimated by multiplying activity level (in energy consumption) by the baseline emission rate established using the curve possibly in conjunction with some adjustment for ambient conditions and engine speed.

2.2.6. Legal and Institutional Considerations

One of the advantages of a credit-based approach is that it would be entirely voluntary and thus would be unlikely to face much challenge with respect to international law. With respect to EC law, however, there could be some legal complications, because allowing ships to trade with land-based sources would probably require modifications of at least two European Directives—the Large Combustion Plant Directive (“LCPD”) and the Integrated Pollution Prevention and Control (“IPPC”) Directive.

In particular, the LCPD contains provisions that require strict emission limits for combustion plants or, in the case of existing plants (those licensed before 1987), national plans that would provide equivalent reductions. Although emissions trading by the existing combustion plants alone (under national plans) would provide flexibility to these sources, the overall emissions from land-based sources would be capped. A credit-based programme involving shipping, on the other hand, would involve increasing emissions from the land-based sources, and therefore it may be necessary to modify the legislation to provide for an increase when purchasing credits from marine vessels. (Of course, under the credit-based approach, the increased emissions from land-based sources would be compensated for by decreased emissions from shipping sources.)

As described in the NERA (2004) report, a significant obstacle to developing a credit-based programme would be the relative dearth of land-based trading schemes for SO₂ or NO_x. At present, only the Dutch have implemented a scheme for trading emissions as part of compliance with the Large Combustion Plant Directive. It is not clear what would be required to allow other land-based sources or, for that matter, ships to participate in the Dutch national plan. Other Member States (including the UK) are looking into the possibility. In the longer term it is therefore conceivable that land-based emitters in trading regimes could trade emissions with the maritime sector, provided that the desired environmental objectives were not compromised. If such trading schemes begin to take firmer shape in the next year or two, then there might be scope for, and interest in, including maritime sources.

In the absence of a land-based trading programme, a credit-based approach could also be implemented via a government subsidy programme. An approach similar to this is being pursued by the SCAQMD, where a number of ships participating in the credit generation programme received government funds (ultimately from other private sources) to remanufacture old engines or install new ones. These credits are then used by the District to offset emissions overruns in the cap-and-trade programme from these other sources. A similar approach would be legally feasible in the EU as current EU state aid rules allow Member States to subsidise the development and take-up of low emission shipping technologies. Of course, the major challenge in this approach would be obtaining the funds to provide the subsidies.

2.3. Implementation Parameters

This section discusses the key elements that would be involved in implementing a credit-based programme to reduce shipping emissions.

2.3.1. Permitting and Verification

Verification of emission reductions raises two central issues. The first is who would be responsible for performing the verification, and the second is when the credits would be issued. These are addressed in turn below.

One option for verification would be to make the government or competent authority responsible for verifying all credits, collating emissions data, and tracking participants. This could involve a significant expenditure of public resources.

An alternative approach would be to give the responsibility for verifying credits to third-party participants—independent auditors with the responsibility for ensuring accuracy. This approach is advocated by the Demo project and would have the advantage of placing a significant portion of the administrative burden on a third party. This could make the verification of emissions reporting on a par with the verification or auditing of financial accounts, which is seen as a perfectly legitimate means of ensuring compliance with legal requirements. Of course, a potential disadvantage of this approach is that it would give the competent authority less control over the environmental integrity of the credits.

With regard to timing, there are essentially three alternatives—credits could be issued in advance, continually, or at the end of some period.

In the SCAQMD programme, credits are issued at the outset of each (annual) activity period on the basis of a ship's projected activity level. This has the advantage of making the programme more attractive for participants but can also create perverse incentives. If feasible, it would be desirable to issue credits more frequently—possibly even continuously—as they are generated. On balance, it seems sensible to allow third parties to verify baselines and then allow governments to issue credits as they are generated, assuming a suitable enforcement strategy can be developed. In any case, effective verification would require a sound method of monitoring.

2.3.2. Monitoring and Reporting of Emissions

The monitoring approach taken in any emissions trading programme is critical because it determines the programme's flexibility and accuracy. Generally speaking, the more detailed the monitoring, the more closely aligned participants' incentives are with the environmental objectives of the programme. In addition, careful monitoring can help to guarantee environmental credibility.

The SCAQMD approach to monitoring and reporting provides some useful background on the characteristics that might need to be tracked in an EU credit-based scheme. As with many programmes, SCAQMD requires monitoring of a variety of parameters:

§ *Location.* Although the value of credits is not differentiated by location, global positioning systems (“GPS”) monitoring is required to ensure that ships remain within covered waters at all times. The ship operator is required to record and maintain the GPS data to verify location, as discussed below. This information is transmitted to a secure on-board server every 20 minutes and then collected by District officials quarterly.

- § *Emissions Factor.* The emissions factor for each vessel is tested on a periodic basis, approximately every 18 months. This factor is then used throughout the subsequent period as the basis for credit estimation. The District is also permitted to conduct unannounced inspections of emissions rates at any time.
- § *Activity Level.* Shipowners are required to monitor and maintain records of the gallons of fuel purchased. These records are then turned over to District officials. Because location is also monitored regularly, fuel usage can be checked against location information. This process is simplified because only captive vessels are included.
- § *Energy Consumption Factor.* This factor, which relates fuel consumption to energy usage (in kWh), is measured periodically along with the emissions factor.

The two sections below discuss how *emissions* could be monitored for SO₂ and NO_x, drawing on the experience from this SCAQMD programme, as well as stationary source cap-and-trade programmes and the findings of the Demo project. After these sections, we cover two issues that are common to both pollutants: monitoring of location and reporting.

2.3.2.1. Monitoring SO₂ emissions

When no technology (i.e., no scrubber) is installed to reduce SO₂ emissions, the emissions rate can be calculated directly from the sulphur content of the fuel. Of course, some ships have several fuel tanks, which may contain different fuel batches (with different sulphur contents), complicating the calculation of SO₂ emissions. Consequently, there needs to be a logged record of which fuel is used at a given time. If a scrubber is installed, a ship's emissions rate cannot be calculated as a direct function of its fuel type but rather is dependent on the scrubber's effectiveness, which can vary significantly across different technologies, vessels, and even during the course of a given ship's operations. Nonetheless, the scrubber's effectiveness could be measured periodically while the vessel is in port, with this emissions rate then applied in future operations. (This is similar to the SCAQMD approach for NO_x.)

If these simple relationships were used to estimate the emissions rates, then it might be sensible to incorporate a reasonably simple approach to ensuring compliance. For example, the measurement of emissions rates under a relatively simple monitoring regime could involve merely requiring affidavits from shipowners certifying that they will use a scrubber or a certain type of fuel in covered waters. (Such a regime would need to be backed up by a relatively strict enforcement regime, as described below.) For scrubbers, these affidavits would need to be coupled with periodic tests of scrubber effectiveness.

To estimate fuel consumption for these simple cases, authorities could require shipowners to submit verified fuel receipts or ships' logs recording fuel usage and type. Fuel usage could also be estimated relatively simply by combining location information with estimates of ships' fuel efficiency (in kg per nautical mile). It is also conceivable that fuel consumption could be measured for relatively minimal cost, using a fuel metering device that can be installed on board vessels to track changes in the fuel level (Sarkar 2005). However, as fuel metering has not been proven for this purpose, particularly on very large ships, the approach would need to be tested before incorporating it into any formal regulation. In this regard, one possible approach would be to record engine effect continuously and correlate these data to fuel consumption.

For the purposes of on-board monitoring, total SO₂ emissions would probably be estimated by multiplying the SO₂ concentration in the exhaust gas by the total amount of exhaust gas generated. Although the amount of exhaust gas flow could be measured directly, such an approach is relatively untested and could be very costly. For this reason, the IMO Technical Code also allows for the approximation of total exhaust gas flow (per hour) using the fuel consumption rate, the carbon content of the fuel, and the dry exhaust concentration of CO₂. Because carbon content is relatively consistent across most fuels, a default value can be used for this parameter. Moreover, there is a consistent relationship between the rate of carbon consumption in fuel and the rate of CO₂ emissions in exhaust. Thus, estimates of total SO₂ emissions could be developed with reasonable accuracy by measuring three parameters: SO₂ concentrations in exhaust gas, CO₂ concentrations in exhaust gas, and some estimate of the fuel consumption rate (which can be estimated by monitoring engine power).

The concentration of SO₂ in the exhaust, combined with the estimated exhaust flow rate and summed over some period of time, gives total SO₂ emissions with, according to the Demo results, an uncertainty in the range of 15 to 20 percent.

Both the SO₂ and CO₂ concentrations in the exhaust gas could be measured directly by monitoring the exhaust with a non-dispersive infrared (“NDIR”) unit, a technology approved by the US EPA for similar purposes. As part of the Demo project, this technology was tested successfully on board a passenger ferry (the *Pride of Kent*) to measure SO₂ concentrations and aboard two vessels (*Stena Jutlandica* and *Manon*) to measure CO₂ concentrations. Further discussion about these technologies and their likely costs is provided in the annex.

The fuel consumption rate (in g/hr) is very difficult to measure once an engine is installed, and it may be more cost effective to use manufacturer estimates of fuel consumption rates at various engine load settings.

There is also some middle-ground between periodic and continuous monitoring. A hybrid approach could involve estimating the emissions rates less frequently but continuously monitoring fuel usage. This scheme would represent something of an intermediate approach between the more simplistic and complex alternatives described above. This would especially be effective for ships using low-sulphur fuel (as opposed to installing scrubbers), since there is little variation across ships in the relationship between the sulphur content of the fuel and the ultimate emissions rate.

Given the importance of accuracy for a credit-based approach, detailed monitoring of both SO₂ emissions rates and fuel usage could be valuable. However, high monitoring costs could reduce participation and any corresponding cost savings or environmental gains. In addition, the findings of the Demo project suggest that periodic monitoring can provide reasonable accuracy for the measurement of SO₂ emissions. These competing factors would need to be weighed against one another.

2.3.2.2. Monitoring NO_x emissions

In contrast to SO₂ emissions, NO_x emissions cannot reasonably be measured as a function of fuel consumption alone. Total NO_x emissions can be better estimated by multiplying the NO_x emissions rate (in g/kWh) and the total energy expended (in kWh). Much like SO₂, there is a wide range in terms of the complexity of monitoring that could be required.

NO_x emissions could be estimated with a small investment of resources using the approach identified by SCAQMD, which was described above. The approach involves periodic

monitoring of NO_x emissions rates (in g/kWh), energy consumption factors (in g/kWh), and fuel usage (in grams). While it is likely to be less accurate than continuous emissions monitoring, this approach does have the advantage of involving relatively little cost. In addition, SCAQMD officials note that periodic testing can be fairly effective because new engines are built to last 30 to 40 years. Thus, over a period of even a few years, emission characteristics change little (Sarkar 2005).

Continuous monitoring of NO_x emissions would ultimately involve tracking the same parameters that are required of SO₂ monitoring, including CO₂ concentrations in the exhaust fuel and engine power (which can also be used to estimate the fuel consumption rate). These components could be monitored in the manner described above. In contrast to SO₂, however, ambient parameters must be monitored to correct the emissions to standardised conditions.

Of course, the NO_x concentrations in the exhaust gas would also need to be tracked. NO_x concentrations could be measured with a chemiluminescence analyser, as recommended in the IMO Technical NO_x Code. The methodology was tested onboard two ships in the Demo project and led to uncertainty levels in the NO_x concentrations of the order of five percent.

Because NO_x emissions are far more variable than SO₂ emissions, continuous monitoring may be preferable to periodic monitoring for NO_x. Again, however, it will be important to weigh the increased costs of continuous monitoring against the additional accuracy.

2.3.2.3. Position monitoring

While many monitoring regimes require only the tracking of emissions, the mobile nature of maritime sources requires a more complex approach. As noted, the SCAQMD programme simplifies this issue by allowing only ships that remain within District waters at all times to participate. Even there, though, some location monitoring is necessary in order to ensure that only captive vessels are included. But an EU programme, where both the scope of ships included and the geographic coverage of the programme are much broader, would require even more complexity. Because the programme would include non-captive vessels, there would be a need to determine which emissions occur in covered waters (i.e., emissions occurring within the geographic limits of the programme) and therefore generate credits.

Tracking location would be facilitated by the presence of the GPS technology that is installed on board virtually all ships. Assuming that the EU programme would include a broader array of ships than those covered by the SCAQMD, it would be necessary to tie location information to emissions data. The results of the Demo project suggest that this could be accomplished relatively easily.

In addition to on-board GPS technology, universal ship-borne Automatic Identification System (AIS) transponders have been required on all new-build ships since 2002 and will be required on all existing ships by 1 July, 2008. These AIS transponders would allow authorities to determine the location of any given ship when it is within radio distance. Information from this system could then be used to cross-check data recorded in on-board monitoring.¹⁵ This level of location monitoring would probably be required for either SO₂ or NO_x.

¹⁵ See the Coast Guard Navigation Center for more information: <http://www.navcen.uscg.gov/marcomms/ais.htm>. See also the DEMO project at <http://www.pwc.com/se/swe/about/svcs/demoproject/index.html>.

2.3.2.4. Reporting

Whichever monitoring approach is selected, it will have to be combined with some means of reporting the findings to the programme administrators. There are two basic approaches to reporting continuous monitoring data: periodic downloads or regular transmissions. In either case, data would first be recorded on board.

Periodic downloading of emissions data would be relatively straightforward; shipowners would be required to download emissions information to a secure on-board hard drive. All emissions data would then be downloaded by authorities only when ships were in port or at other specified times.

Regular data transmissions would be more complex, particularly complicated by ships' wide travels. Continuous data transmissions would almost certainly require the installation of additional on-board satellite communications technology; existing GPS and internet technology would likely not be sufficient. In one onboard test that has been performed, data were transmitted using the global system for mobile communications ("GSM"). GSM is among the more affordable satellite technologies but did experience some transmission delays in the test. Alternative satellite technologies should be explored before anything specific is recommended. Note that emissions data could be transmitted continuously or at regular intervals (e.g., hourly or daily).

The ultimate selection of a reporting technology will require further testing of satellite options. Ideally, a satellite option would be selected so that continuous reporting could be achieved. However, if an effective and affordable approach cannot be found, periodic downloading may be the only realistic option.

2.3.3. Determining Compliance and Enforcing the Programme

While setting the baseline is probably the most important issue in designing a credit-based programme, enforcement may be the biggest issue in implementing one. Like monitoring, enforcement is critical because it determines the effectiveness of the programme. Lax enforcement can lead to abuses and credits that are inappropriately allocated, while a strict enforcement regime can reduce cheating but be very costly to administer.

Although the breadth of the SCAQMD programme differs greatly from the programme being discussed here, officials administering that scheme do point to enforcement as one of the most critical issues they have dealt with (Sarkar 2005). The SCAQMD programme stipulates the following penalties:

- § *Actual Activity Level Exceeds Projected Level.* If, at the end of the period, it is determined that the actual activity level exceeds the projected level, the operator must surrender credits equal to 110 percent of the shortfall (i.e., there is a 10 percent penalty).
- § *Vessel Travels Outside of District Waters.* If a vessel travels out of District Waters (except for up to two maintenance trips per year), all credits for the current period are voided.
- § *Information Falsified on Application.* If any information on a vessel's application form has been falsified (e.g., the emissions rate), the District may: (1) void all previously issued credits, (2) designate the applicant ineligible for any future credits, and/or (3)

assess the 10 percent penalty (i.e., require the applicant to surrender credits equivalent to 110 percent of those generated).

The penalties here are relatively modest, but they provide helpful background on the types of situations in which penalties might be levied. Of course, the SCAQMD is limited by its resources and, specifically, its lack of any enforcement patrol boats. Ideally, any system implemented in the EU would have a greater scope.

An important feature of credit-based schemes is that a less-detailed monitoring regime could necessitate more aggressive enforcement, while less enforcement would probably be required for more complex monitoring. For example, a programme in which shipowners merely signed certified statements promising to operate control technologies or use certain fuels would likely require frequent unannounced inspections. On the other hand, some enforcement could fall to third parties in a scheme with continuous monitoring and third party verification, if third party verifiers were held liable for breaches. Even with frequent inspections, however, it could be difficult to ensure continuous operation of control technologies and low-sulphur fuel usage without on-board monitoring.

There are several components that would be included in any enforcement regardless of the rigour of the enforcement regime.

Random inspections would certainly form one critical component of any enforcement regime. These inspections would be intended to confirm—where relevant—the continued operation of installed abatement technologies, monitoring equipment, and the type of fuel burned. Such inspections have been suggested in the context of the Swedish Maritime Administration's differentiated dues programmes (SMA, *not dated*). These inspections have focused primarily on the sulphur content of fuel; different procedures would need to be developed to inspect for NO_x equipment or scrubbers.

Penalties are another important aspect of enforcement. If appropriately constructed, even a relatively simple enforcement regime can prevent abuses if the incentives are structured correctly. In this regard, the level at which penalties are set can play a critical role. Indeed, the experience of the US Acid Rain Program suggests that stiff penalties can play an important role of meeting programme goals (Stavins 2000).

Any enforcement regime in the EU could face legal difficulties in enforcing penalties on foreign-flagged vessels. SMA officials have emphasised the advantage of being able to hold ships in port if environmental compliance is in question. Under a credit-based programme, officials might lack that authority. Thus, legal means of enforcing any levied penalties would need to be explored—for example, it may be possible to agree a contract between competent authorities and vessel operators that opt into a credit programme.

2.3.4. Programme Administration

The majority of administrative responsibilities for the authorities would be likely to come in the three implementation categories identified—permitting and verification, monitoring and reporting, and enforcement. The extent of the administrative resources that would need to be devoted to each of these would depend upon the way in which the programme was structured in each of these areas:

- § **Permitting and Verification.** Administration could involve the certification of credits. Relying on qualified third parties for the auditing and verification of credits could substantially reduce the authority's obligations to consist essentially of supervision.

- § **Monitoring and Reporting.** The authority could be responsible for specifying the monitoring techniques, overseeing the installation of monitoring equipment, and/or collecting emissions and location data. The responsibilities for monitoring would likely fall mostly to the shipowners, but a certain amount of supervision would almost certainly be needed.
- § **Enforcement.** Administrators could be responsible for conducting random investigations, inspecting monitoring technologies, and levying penalties. These obligations could be substantially reduced by requiring a strict monitoring regime and making third parties responsible for monitoring and verification.

Like most of the components identified, the level of administrative resources that would be necessary to oversee the programme could vary greatly. In order to ensure the overall cost effectiveness of the scheme, it would be necessary to keep administrative costs relatively low. This could be achieved by allowing third-party verification (paid for by shipowners) and requiring shipowners to install fairly rigorous, tamperproof monitoring systems.

3. Consortium Benchmarking

This section considers consortium benchmarking, an approach that has been proposed as a means of allowing a group of vessels to achieve a target average emissions rate as a group. We begin this chapter with some background on benchmarking and voluntary consortia, and then provide brief summaries of existing programmes that have used the approach. We then discuss the detailed elements of the approach, divided into design and implementation features.

3.1. Background on the Consortium Benchmarking Approach

In the approach considered here, vessels would have the option of joining a consortium that would voluntarily commit to achieving an average emissions rate, known as the benchmark. The specific proposal we consider allows for this programme to be voluntary, i.e., ships could form consortia and trade among themselves to achieve the average rate (which would be below the “BAU regulatory case” to account for the cost savings that flexibility would provide and avoid environmental backsliding).

Benchmarking emissions trading programmes¹⁶ identify a specific emissions *rate* to apply to covered activities and require that the average emission rate (weighted by activity level) from these activities does not exceed the benchmark level. In contrast to a credit-based approach, there is no need to establish and certify a baseline emissions rate in the case of benchmarking, because the benchmark rate effectively serves as the baseline. Sources subject to the programme can trade credits among each other based upon set formulas for calculating credits (and debits). As with any emissions trading programme, trades are voluntary, and are only entered into when they are mutually beneficial to both the buyer and seller. Thus, as with the credit-based approach, where different vessels face different costs of abatement, this approach can lead to cost-savings to achieve a given environmental target. It can also be used to achieve a stricter environmental target at lower cost than a less flexible approach.

In the context of shipping emissions, a benchmark trading programme would set an emission rate for participating ships and would allow ship owners (or operators) to buy and sell emission “allowances” or credits depending on whether their emission rate was above or below the benchmark. Vessels would always have the option to forgo trading by adopting abatement measures so that their emissions rate was equal to or below the benchmark. With a benchmark trading programme, participating ship owners/operators would have the additional option of reducing their average emission rates below the benchmark and selling (or banking) credits, or of having an average emission rate above the benchmark and buying credits.

The policy discussed here would involve trading “consortia.” A consortium would consist of a group of vessels that voluntarily join together and ensure that their emission rate as a group is below the benchmark rate. Although participation in the consortium would be voluntary, it is voluntary in a sense that is different from the credit-based approaches. Under credit-based approaches, vessels may only volunteer to abate beyond business as usual or some pre-existing target. In the consortium approach, some vessels can choose not to meet the existing

¹⁶ Benchmarking programmes have been referred to by many other terms, including “rate-based,” “intensity-based,” “averaging,” “performance-based,” and “growth indexing” programmes. Shipping Emissions Abatement and Technology has proposed a similar approach that they term “offsetting” via “syndicates”.

emissions requirement provided they can find other vessels to offset their higher emissions rates with lower emission rates. Whereas the credit approach can be implemented in the absence of a pre-existing emissions requirement, the benchmarking approach cannot.

3.2. Existing Experience with Benchmarking Trading Programmes

There are several examples of benchmarking programmes, as well as many examples of voluntary trading schemes. We are not aware of any existing programmes that combine these two features—that is, where a subset of sources can volunteer to participate in a trading programme but where no sources are required to participate.¹⁷ This section provides brief overviews of three benchmarking examples:

- § fuel economy standards for automobiles;
- § mobile source averaging, banking and trading (“ABT”) programmes that began in the early 1990s; and
- § the proposed California Air Resources Board scheme for reducing ship fleets’ NO_x and PM emissions by 50 percent (for frequent visitors to Californian ports).

3.2.1. Fuel Economy Standards for Automobiles

Since the 1970s, US automobile manufacturers have been required by law to ensure that the average fuel efficiency of all new vehicles they sell meets certain standard rates. The EU has also secured voluntary agreements from auto manufacturer associations to achieve certain average minimum vehicle efficiency standards. In the US, the standards apply to all passenger cars and light duty trucks (which include sport utility vehicles), but there are different benchmark rates that apply to the two vehicle classes. Each year, manufacturers are required to sell a sufficient number of vehicles with fuel efficiency above the standard rate to offset the lower efficiency of vehicles whose fuel consumption does not achieve the standard. Thus manufacturers are able to “trade” credits within each vehicle class. Manufacturers are not, however, allowed to trade between classes, and they are not able to trade with other manufacturers—averaging can only occur over each manufacturer’s own fleet. There is some limited ability for manufacturers to carry over credits between years, so that a deficit in the current year can be covered by surplus credits from previous years. In contrast to the approach proposed here, the regulation applies only to *new* vehicles, and the average emissions rate is weighted by vehicle *sales*. Because activity levels are not accounted for, there is no guarantee that actual average fuel consumption will match the target rate.

3.2.2. Mobile Source Averaging, Banking and Trading Programmes

The US Environmental Protection Agency has also designed policies that apply emissions benchmarks for NO_x and VOCs to new engines for a wide range of mobile sources, including marine vessels.¹⁸ These programmes, collectively known as “averaging, banking, and

¹⁷ A similar example is the Chicago Climate Exchange, where participants are able to trade emission reduction credits that they make voluntarily. There is no existing regulatory requirement that participants are obliged to fulfil, however, so it is not entirely analogous to the policy being considered here for ships.

¹⁸ The mobile source categories with ABT programmes now include the following:

- Automobiles and light-duty trucks;

trading” (or “ABT”) programmes give manufacturers the flexibility to trade surpluses and shortfalls relative to the regulatory benchmark. Unlike baseline credit programmes, the ABT programmes allow manufacturers to generate surplus credits automatically using a predetermined formula (rather than requiring case-by-case baseline certification). The three uses of surplus credits that give these programmes their name include:

- § “averaging” emissions over all engine types produced by the manufacturer in the same model year,
- § “banking” credits for use in offsetting excess emissions from engines produced in future years, and
- § “trading” credits to another firm to offset emissions from that firm’s engines.

Averaging and banking have been much more heavily used than trading, possibly because the small number of competing engine manufacturers do not wish to become reliant on the purchase of credits from their competitors. It is also likely that there are lower transaction costs associated with keeping the transaction within the firm, and it is also possible that the differences in abatement costs are more pronounced among engine types made by any single manufacturer than across engine types made by various manufacturers.

The calculation of emissions credits (and “debits”) is based upon clearly established factors that differ somewhat by mobile source category. The factors typically include the difference between the applicable emissions standard and the engine family’s emissions, estimated sales of each engine in the relevant model year, estimated average annual engine use in hours, the power output of the engine family, and the expected useful life of each engine.

Because the policy only applies to new engines, “monitoring” focuses on the testing of a sample of each engine model that a manufacturer produces. Since this would be required anyway to demonstrate compliance with any emission limit regulations, no major additional mandatory costs are imposed by ABT.

The experience with ABT suggests that trading not only provides flexibility and cost savings, but also that it allows more ambitious environmental targets to be adopted. In the case of marine outboard and personal watercraft engines, for example, the EPA set the average emissions standard in part on the basis of a marginal cost curve that assumed emissions trading. If the ABT provisions had not been included, the average emissions standard would likely have been less stringent to accommodate the higher costs of compliance for some manufacturers and engine families, or different standards would have been established for each engine family.

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- Heavy-duty truck engines;
 - Large non-road diesel engines used in construction, agriculture, and other uses;
 - Locomotive engines;
 - Marine outboard engines and personal watercraft;
 - Small engines used in various lawn, garden, and other applications.

The US Environmental Protection Agency Office of Air and Radiation website has information on various ABT programmes. See <http://www.epa.gov/oar/oarhome.html>.

3.2.3. Proposed CARB Scheme to Reduce Emissions from Shipping

The California Air Resources Board (“CARB”) has proposed a scheme to reduce emissions of PM, NO_x, and other air pollutants from ocean-going vessels in the state’s coastal waterways (CARB 2004). Beginning January 1, 2006, no vessel that calls at California ports or facilities may run its auxiliary engines unless the engines operate on marine gas oil with sulphur content of 0.2 percent or less by weight. The maximum value will fall to 0.1 percent two years later. In the form of the scheme proposed in November 2004, “frequent visitors,” defined as ships that enter California ports or facilities five or more times a year, are required to reduce their emissions of PM and NO_x by 50 percent over and above the reductions achieved through the use of low-sulphur fuel for auxiliary engines. These more stringent requirements may be satisfied through the use of shore-side electrical power, engine modifications, exhaust treatment control, alternative fuels, and operational controls, such as reductions in speed.

Ships classified as frequent visitors must submit to CARB a vessel emission reduction plan (“VERP”) outlining how the additional requirements will be met. Shipping operators may come together in groups that jointly achieve the required emissions targets (i.e. “consortia” in our terminology) if they can demonstrate in their VERPs that the aggregate reductions made by the group of vessels will be greater than or equal to the sum of reductions required of each vessel treated individually.

This “averaging” or benchmarking feature of the CARB scheme was not included in the most recent draft proposal (CARB 2005), but these provisions of the scheme are expected to be developed in more detail later this year.

3.3. Key Design Elements of Consortium Benchmarking Trading Scheme

This section discusses five key elements that would be involved in the design of a consortium benchmarking scheme for the maritime sector.

3.3.1. Participation in the Consortia

Participation in the consortium would be entirely voluntary—the alternative would be simply to comply directly with whatever existing regulation applied. As with credit-based trading programmes, there are a number of different ways that participation in a consortium might be limited. However, because it is unlikely that government officials and other regulators or competent authorities will know for certain which vessels would be able to benefit most from the flexibility afforded by consortium membership, the default policy, in the absence of countervailing circumstances, should be to err on the side of inclusiveness.

3.3.1.1. Geographical restrictions: Location of vessel activity

As with the credit-based trading programme, there might be a desire to restrict the eligibility of consortium participation only to vessels plying certain waters. One obvious candidate would be vessels that operated in or passed through a SECA. A certain port or group of ports also might wish to reduce emissions in their vicinity, and therefore might encourage “local” vessels to form a consortium that would jointly achieve certain emissions targets. Finally, for ease of administration, port authorities, Member States or the Commission might wish to restrict participation only to vessels that spent a certain proportion of their time within their

respective waters, or to vessels which call regularly at their ports, as in the proposed CARB scheme. As discussed above, monitoring or enforcing emissions reductions from ships with international routes would potentially be more difficult than doing the same for vessels that are always or almost always in regional waters.

Because administration of consortia is likely to be handled, at least initially, by the consortia themselves, it seems reasonable to extend eligibility to vessels that do not spend all of their time in the waters where emissions are to be reduced. Vessels that pass through the relevant waters only infrequently are the most likely to wish to purchase “credits” from consortium members that have generated a surplus. Provided the policy is appropriately designed, including these vessels is likely to yield greater environmental benefit and greater cost savings because the pool of potential participants will be larger. However, as discussed below, it is of course entirely appropriate for ports, Member States, or the Commission to restrict the region over which emissions and emission rates should be averaged. It is of less benefit to the EU if a vessel reduces air pollutant emissions in areas distant from the EU.

3.3.1.2. Restrictions on vessel size or type

In principle there is no reason to restrict the size or type of vessel that would be allowed to be a member of a consortium. It would be possible to restrict membership to only the largest vessels, but excluding smaller vessels would eliminate some of the heterogeneity that creates the potential for cost savings from trading. For example, larger vessels are probably more likely to install abatement technologies that have high capital costs, because their higher fuel use would justify the potential cost savings, whereas smaller vessels might prefer not to install technologies if they could instead purchase credits from larger vessels.

Another reason not to restrict the type of vessel participating is suggested by the experience with ABT programmes in the US. Trading between companies under these programmes has been limited in part because the companies are direct competitors. If a consortium were restricted only to large container cargo vessels, or only to oil tankers, this could result in similar disincentives to trade. On the other hand, including a wide range of vessel types and activities would increase the likelihood that most of the participants would not be direct competitors.

3.3.1.3. Vessel flag

Under some circumstances, it may be desirable to restrict participation in a consortium to vessels flagged from a particular Member State or from EU countries. The reasons for such restrictions would derive from the potential difficulty verifying and enforcing compliance with consortium rules for foreign-flagged vessels. For example, the legal basis for fines of foreign-flagged vessels would be less certain than the basis for fines of domestic vessels. It may also be more difficult to board foreign-flagged vessels for surprise inspections.¹⁹ As discussed below, if foreign-flagged consortium members were able and/or willing to cede some of their traditional immunities, at least with regard to the limited circumstances covered by compliance with the rules governing consortia, this could facilitate their participation in a consortium.

¹⁹ These enforcement issues are also relevant to current expected policies in the SECAs. Enforcement is likely to vary with different coastal states.

3.3.1.4. Standing of vessel or of vessel owner or operator

Because participation in a consortium will require a substantial degree of self-regulation, at least during any initial voluntary period or pilot phase, governments may wish to restrict participation to vessel owners, operators, or vessels themselves that are certified to a particular environmental standard—for example, ISO 14001. Governments might also require that participants meet certain standards of accounting, or that they have a minimum level of insurance cover or financial standing to guard against the possibility of defaulting on obligations. They might also require that vessels or operators have not committed any recent violations while operating in port, Member State or EU waters.

These types of requirements may be in the interest not only of governments and competent authorities, but also of other consortium members themselves. A consortium may wish to impose similar restrictions on its membership, since the consortium as a whole is likely to be held responsible, at least in part, for any lapse.

One final issue related to the issue of “standing” are the rules governing the joining and leaving of consortia. We reserve discussion of this issue for Section 3.4.4 on Programme Administration.

3.3.2. Covered Pollutants and Incentivised Measures

A benchmarking scheme would inherently be tailored to cover certain control measures, and existing regulations mean that it would only make sense for certain pollutants. This section covers these issues.

3.3.2.1. Covered pollutants

A consortium benchmark trading approach could be implemented in conjunction with the proposed Sulphur Directive, which is described in Chapter 1. Indeed, amendments to the Directive that would open the possibility for such a trading programme have been proposed. The case of sulphur emissions appears to be well-suited to the benchmarking approach, either applied to emissions within the SECAs or within EU waters in general.

Currently the only requirement for NO_x emissions from ships is given by the IMO NO_x curve, which applies exclusively to new engines (from 1 January 2000). The requirements imposed by the NO_x curve are generally held not to be particularly binding—that is, engine manufacturers would likely have produced engines conforming to the standards established by the NO_x curve even if the curve did not exist as a requirement. Thus it is not clear that there are any sources that face a NO_x requirement that would prefer to be able to comply with it via some other mechanism such as benchmark trading. As a consequence, it may be difficult to cover NO_x under a benchmark trading programme or to incentivise abatement of NO_x emissions unless further regulations that go beyond the IMO NO_x curve are developed. For the purposes of our analysis, we assume certain regulatory requirements, but these are purely illustrative.

For similar reasons it may be difficult to implement a benchmark trading scheme to cover maritime emissions of CO₂, PM, or VOCs. Without new legislation requiring vessels to meet certain specific emissions requirements, no vessels would benefit from the compliance flexibility that trading can provide. We do not assess the effects of a benchmark trading programme on these emissions.

3.3.2.2. Covered control options

Regarding the types of measures incentivised, one general point regarding benchmarking approaches is worth emphasising. Depending on the units that are used to define the benchmark, different types of measures may be incentivised. For example, if benchmarks are defined in terms of emissions per unit of fuel input, the benchmark trading programme will not incentivise measures that improve vessel efficiency and reduce fuel consumption—even though such measures may represent cost-effective ways of reducing emissions. However, input-based approaches are likely to be the easiest forms of benchmarks to define and implement. The alternative would be to define “output-based” benchmarks—for example, in terms of emissions per tonne-kilometre or per passenger-kilometre transported. Although output-based benchmarks would be able to incentivise various types of efficiency measures, they would be much more difficult to apply consistently to a broad range of vessel types.

3.3.3. Baseline Emission Rates

Perhaps the most important design element of the consortia benchmarking approach is the benchmark rate itself (or, where multiple rates are appropriate, the set of rates that would be established for various types of ships). This involves determining what type of rate to set, i.e., what activity to use as the basis for the rate, and how the rate should differ for different vessel types, if at all.

In general there are two types of emission benchmarks commonly used, based either on input or output. An input-based benchmark could be expressed as grams of emissions per litre of fuel, or as grams of emissions per joule of energy input. An output-based benchmark also could be defined in terms of energy, although because it would be expressed in terms of *output* energy it would reflect the conversion efficiency of any engines. Alternatively, an output benchmark could be expressed in terms of the service provided by a particular vessel—for example, kg of emissions per tonne-kilometre of cargo transported, or grams of emissions per passenger-kilometre travelled. As discussed above, benchmarks defined in terms of certain units will be better able to incentivise some types of abatement measures than others. In particular, service output-based measures are most likely to be able to incentivise the full range of efficiency measures that vessels might implement. We consider the applicability of such benchmarks to the emissions considered in this study below.

3.3.3.1. SO₂ benchmark rates

Sulphur emission rates depend upon the sulphur content of fuel used. The main fuel used by marine sources is heavy fuel oil (“HFO”), which has a global average sulphur content of about 2.7 percent by weight. The easiest benchmark to use for SO₂ may be one that expresses emissions per unit of energy output. Based on the average energy content of HFO, this corresponds to an emission rate of approximately 11 grams of sulphur per kilowatt-hour of energy (g S / kWh). Meeting the current SECA fuel restrictions of 1.5 percent sulphur HFO would involve reducing the emissions rate by approximately 45 percent to 6 g S / kWh.²⁰

²⁰ The average emission rate is likely to mask variation in the sulphur content of fuels used. For example, some vessels actually run on marine diesel oil (“MDO”), which contains less sulphur than HFO, and other vessels may use HFO with different sulphur content. It may be important to consider this variation to understand better the “business as usual”

One possible value for this benchmark would be to require an average emission rate within the European SECAs to correspond to a sulphur content of 1.5 percent sulphur fuel (hereafter, a “six-gram” rate). A pilot benchmarking project being conducted by Shipping Emissions Abatement and Technology (“SEAA”) has chosen to use this rate as its target. Participating vessels will be assigned emission rates and will keep track of fuel use. The consortium will then calculate total emissions from vessels’ activity and divide it by the total energy use to find the average overall emission rate for the consortium.

Unfortunately, there are potential problems with using a six-gram rate as a benchmark if combined with the currently proposed Directive, because it was never designed to be a trading average under MARPOL Annex VI, and because it could reduce the environmental benefit achieved by the scheme. The problem arises because the Directive, as currently written, already provides for some flexibility of compliance. Operators can choose to run on 1.5 percent sulphur fuel, but they may also be able to use seawater scrubbing or some other similar form of abatement. Scrubbing is expected to reduce emissions to 2 g S / kWh, significantly below the six grams that would be required by the benchmark. For many vessels, however, the cost of scrubbing may be substantially lower than the cost of low-sulphur HFO (Entec 2005a,d). As a consequence, the expected average emission rates in SECAs under the regulations currently in place may be closer to 4 or 5 g S / kWh.

If the consortia were only required to meet the six-gram benchmark, we can assume for the sake of argument that every vessel planning to install scrubbers would wish to be a member of a consortium. Every vessel remaining outside a consortium would therefore by assumption be running on 1.5 percent sulphur fuel. Now, however, some of these vessels would be willing to pay the consortium to allow them to run on standard 2.7 percent sulphur fuel. As more vessels opted into the consortium the average emission rate achieved by its members would rise until it was equal to the benchmark—here set at the 6-gram or 1.5 percent level. Thus the problem with using the 1.5 percent rate to set the benchmark for a consortium is that it would achieve a fleet-average emission rate that is *above* what would be achieved by a flexible regulation *without* trading.

To ensure that the environmental benefit achieved is equal to or greater than what would be achieved under the Directive without trading, it would be necessary to induce *additional* vessels to install scrubbers. Vessels that under BAU would not install scrubbers would be given incentives to install them via the payments made to the consortium by vessels running on 2.7 percent sulphur fuel. The level of the price needed to induce additional entry is uncertain. It is important to note, however, that simply setting the benchmark at a lower rate would not be sufficient to ensure additional environmental benefit unless entry of additional scrubbers is induced.

This potential issue may be less significant if the default regulation that is being compared is one that requires vessels to use 0.5 percent sulphur fuel. In this case, it is unlikely that there would be substantial “overachievement” under the non-trading regulation.

average emission rates and to project more accurately the average rates under benchmark trading. This would require a more detailed investigation of vessel fuel use than has been possible under the scope of the current work.

3.3.3.2. NO_x benchmark rates

As noted in Section 3.3.2 there are currently no binding requirements for NO_x emissions rates apart from the IMO NO_x curve, so it is more difficult to define the level at which a benchmark might be set. Moreover, NO_x emission rates vary substantially more by vessel than do the sulphur emission rates. As described in the introduction, the IMO NO_x curve sets standards for new engines that vary from 9.8 g / kWh for engines rated at high speeds to 17 g / kWh for slow-speed engines. The rates given by the curve do represent an improvement over the emissions of some older vessels, but they do not impose significant constraints on the manufacture of new engines.

The IMO NO_x curve could be used as the basis for a benchmark by requiring members of a consortium to achieve an average emission rate that was some proportion below the rates established by the curve. Of course, in the absence of any additional requirements on vessels to reduce NO_x emissions, there would be very little incentive for them to join such a consortium. For the purposes of this study, we assume that at some point in future a mandatory NO_x emission control policy is implemented that would require the installation of technologies sufficient to reduce NO_x from ships by roughly 20 percent.

Because of the wider variation in emission rates for different vessels, designing a consortium-based benchmarking approach is more complicated for NO_x. One way of designing the scheme would be to restrict consortia membership to a single vessel or engine type. That is, there could be a “slow-speed engine consortium” and a “medium-speed engine consortium.” The benchmark rates would be set somewhere below the rated emissions levels of the cleanest burning (fastest) engines permitted to join the consortium.

Although this approach would simplify the definition of the benchmark rate, it would also limit the potential gains from trading by reducing the number of potential trading partners, and also might face some of the same problems that now beset the ABT programmes caused by participants’ reluctance to trade with competitors. The alternative would be to allow all types of vessels to participate, but for the benchmark rate to change depending on the consortium’s membership. Under this alternative, the consortium’s overall benchmark would be set at a lower rate the more high-speed engines were included. The benchmark would also be variable depending on the relative levels of activity of different vessel types—thus in a consortium with equal numbers of slow- and high-speed engines, but where the slow-speed engines accounted for more fuel use, the benchmark would be closer to the level that would be set for slow-speed engines. The recalculation of the relevant benchmark could be done automatically in “real-time,” but it would introduce additional complexity for consortium members.²¹

²¹ For our empirical analysis, we have not incorporated information regarding the distribution of different emission rates is available, so we have relied on assumptions made by Entec (2002) that vessels on average achieve emission rates of 15 g NO_x / kWh. This assumption eliminates the need to take account of vessel engine type and activity levels in calculating the benchmark.

3.3.4. Geographic and Temporal Differentiation

3.3.4.1. Geographic differentiation

As discussed previously, MARPOL Annex VI establishes rules for the identification of areas of particular environmental sensitivity, in which vessels are permitted to use fuel with at most 1.5 percent sulphur content. The Marine Fuel Sulphur Directive codifies this restriction in European Law, and allows for the establishment of further requirements in the future. Currently, two SECAs have been established in European waters—one in the Baltic Sea, and a second in the North Sea and Channel.

The existence of geographic regions with distinct environmental requirements means that any benchmark trading programme may need to differentiate between them. There are three distinct ways that this can be done in the context of trading:

- § establish separate trading programmes and/or consortia in each region;
- § allow restricted trading (e.g. only in one direction) between different regions; or
- § allow trading between regions to be governed by “exchange rates” for emissions.

As discussed in the context of the credit-based programme, existing scientific evidence and experience with emissions trading programmes both suggest that the effects of emissions from both SO₂ and NO_x can extend over broad geographic areas. However, there is little scientific data to support the development of a complicated scheme of geographic weights at this stage—either for SO₂ or NO_x. Further research in this area would be helpful in developing any complex geographic scheme.

To protect the integrity of the current SECA framework and to ensure that the environmental sensitivities of each region are preserved, it seems appropriate to adopt the first of these three options at present. A consortium or consortia could be established within each region, but they would not be permitted to trade with each other. However, a single vessel passing through multiple regions could in principle be a member of both consortia, and could either purchase or sell emission rights in each region. The second and third options could conceivably be implemented at a later date, but it is likely that they would prove complicated to administer, and the incentives created would be less transparent. Nevertheless, if it were determined based on further study that the differences in environmental effects due to emissions in different regions could be quantified, then, in principle, formulae could be designed that would calculate the required average emission rates in different areas. A vessel’s benchmark requirement would therefore vary depending on where it travelled.

3.3.4.2. Temporal differentiation

3.3.4.2.1. *Banking*

The ability to bank surplus emissions allowances or credits can be an important means of providing additional flexibility to sources covered by an emissions trading programme.²² By

²² See Ellerman et al (2003) for a summary of the gains from banking. Note borrowing of emissions credits could be developed, although its use would raise additional issues that we do not consider in this report.

allowing sources to set aside surplus allowances or credits for use at a later date, banking can help to guard against price spikes (and troughs) that can occur in any commodity market. Banking is also common when the target rate (or the absolute cap) of an emissions trading programme declines over time. Allowing sources to bank credits can encourage early emissions reductions that are then used to delay the onset of the more stringent future targets.

In the context of consortium benchmarking, banking would allow consortium members to “save up” surplus credits that could be used in future to offset emissions of new members that joined the consortium, or that existing members could use if the benchmark rate were expected to be lower over time.

One criticism of banking is that it can lead to a situation in which emissions in subsequent years are higher than current emission rates (or simply higher than future benchmarks or regulatory requirements). This may be of concern particularly if there are annual or seasonal limits on emissions that, if exceeded, can cause substantial harm to an ecosystem or human health (for example, an area may have a certain annual buffering capacity for acid deposition, or emissions above a certain level in any given year may cross a threshold believed to be significant for human health). Under these circumstances it may be appropriate not to allow banking, or to limit its use. For example, the RECLAIM trading programme essentially does not allow banking,²³ whereas the US fuel economy policy for automobiles allows banking but only within three years. Other trading programmes apply a discount to any allowances that are drawn down from the bank above a certain proportion (Harrison 2002).

Because of the experimental nature of the consortium trading approach, as well as the uncertain level of future regulatory requirements, administrators might consider restricting banking. Thus, during each relevant period (for example, every year, every quarter, or even every month) each consortium would be required to demonstrate compliance by showing that its average emissions rate was below the benchmark rate, and any overcompliance could not be used to offset future need.

On balance, however, banking can lead to significant cost savings and should probably be included if administratively feasible.

3.3.4.2.2. Seasonal variation

Some pollutants may contribute to seasonal problems, and therefore it may be desirable to limit them only during certain periods of the year. Where this is true, it may be appropriate for limits to be applied only during this period.

3.3.5. Legal and Institutional Considerations

There are at least two categories of institutional and legal considerations related to the establishment of benchmarking consortia. The first category deals with the relationship of the consortium (and its members) to the government or other authorities that regulate members’ emissions individually in the absence of the consortium. The second set of considerations relates to the internal structures governing consortium members’ relationships and commitments to other members. We consider each of these in turn.

²³ See Harrison (2003).

3.3.5.1.1. Relationship of consortium to government

The biggest current legal obstacle to consortium benchmarking is likely to be the need to revise MARPOL Annex VI and the Marine Fuels Sulphur Directive to allow vessels participating in a consortium—and only those vessels—the right to operate within SECAs (or other restricted areas) using fuel with a higher sulphur content than would otherwise be allowed by law. As discussed below, this raises additional difficult issues associated with enforcement of environmental restrictions on all vessels and verification of vessels’ “membership in good standing” of a consortium.

Apart from the legal requirements, governments or authorities allowing consortia to operate in lieu of achieving individual emissions targets need to have some way of ensuring that the rates committed to by vessels have been achieved. This will be done by establishing monitoring and enforcement regimes, which we discuss below. Even before monitoring, reporting, and enforcement protocols are set up, however, the status of the consortium and its members in relation to the government needs to be established. In the event of a failure to achieve the promised targets it must be known which legal entity or entities should be liable for the breach, and in what way.

It could deter participation if the scope for liability were perceived to be too onerous—particularly for vessels that were actually contributing credits to the consortium, and therefore were achieving lower emission rates than they would have been required to by law. For this reason, it might be appropriate to assign primary responsibility for any lapse to the consortium itself. A consortium that found itself unable to meet its targets would be fined a non-negligible amount and should also be required to make up any promised reductions in emissions that fail to materialise—either directly or by paying into an offsetting fund. It would also be possible for fines to be concentrated on vessels whose emissions were higher than would have been allowed had they not been members of a consortium, although this could expose such firms to additional risks if through no fault of their own the consortium exceeded its targets.

On the other hand, the greatest incentives for compliance would be created if every consortium member were individually liable to the authorities if it did not hold sufficient allowances to meet its obligations at the end of the period. In this sense, the legal obligations would be similar to those under a cap-and-trade programme in which each entity is held legally responsible for covering its emissions. This approach could work in this case as well.

3.3.5.1.2. Relationship of consortium members to each other

One of the most important institutional issues associated with the consortium benchmarking approach is the internal rules establishing and governing the consortium. One potential model for the type of framework required could be provided by Protection & Indemnity (P&I) clubs that operators may join to provide cover for losses. As discussed above, one of the issues to be decided by governments and consortium members are the qualifications a vessel or operator must present if it is to be considered as a member. It would be reasonable to require environmental certification and evidence of insurance cover and solvency. Consortium members would need to sign up to a binding agreement both with each other and with government authorities that would commit them to achieve a collective emissions rate and to individually discharge their responsibilities to pay into the consortium if their emission levels exceeded that level.

Membership in a consortium exposes members to liabilities that they would not otherwise face. As such, it may be desirable for members to commit individually to particular levels of emissions, and to estimate their expected activity levels, as this would assist a consortium to plan in advance and ensure that it is on track to meet its commitments. One reason that such commitments could be useful would be in cases where the failure by a member or members to deliver planned or promised emissions reductions resulted in the consortium being unable to fulfil its overall commitment. In this case, consortia would have a way of assigning responsibility for the breach. Vessels that came up short relative to their promised “surplus” or that generated excess “deficits” could be held liable for any fines assessed to the consortium by the government. It would be up to the consortium members to decide whether binding individual targets were something that members wanted every other member to commit to—however, it probably would not be desirable to involve governments in this process.²⁴

Another issue that members would have to determine is the internal “price” to be paid to vessels that provide credit by vessels that require them. In an active market for emissions credits and allowances, this price would be determined by market transactions. However, initially, it is likely that the price would be set by internal negotiation among members.

The consortium may also wish to require some level of auditing or verification by members to protect itself from liability to the authorities.

Finally, consortium members would need to determine the rules governing entry and exit from a consortium. Once they join a consortium for a given period, vessels should be required to stay in it and be bound by its requirements for that period, and similarly vessels should not be permitted to drop out of a consortium during a period after initially committing to be part of it. Only after reconciliation for the relevant period has been completed (or prior to engaging in activity covered by another period) should vessels be permitted to alter their membership status. Vessels should not, however, be prevented from dropping out of a consortium after all reconciliation of emissions has taken place for a given period. Imposing restrictions on “entry” and “exit” from the consortium would prevent vessels from “shopping around” for the best consortia or the one that best suited their needs.

3.4. Key Implementation Elements of Consortium Benchmarking

This section discusses four critical elements of a consortia benchmarking programme that would need to be addressed on an ongoing basis.

3.4.1. Permitting and Verification

Unlike credit-based approaches, benchmarking programmes typically do not require baselines to be certified—vessels are assigned a standard benchmark rate that they can either meet individually or collectively as part of a consortium.

²⁴ The recent situation on the Dover-Calais ferry route provides an interesting case in point on the potential problems that a consortium might face. After cables snapped at the port terminal in Calais, ferry companies were forced to cut back on their service. If these ferries had been part of a consortium and had been relied upon to generate credits, the suspension of service would have resulted in a significant shortfall of surplus credits, possibly through no fault of the operator. It is not clear who should bear the responsibility in this instance—it could be considered unfair to place all the blame on the ferry operator.

The key verification issue for consortia would be ensuring that the participating vessels were collectively meeting the benchmark rate. To a great extent, this would depend on the monitoring requirements and enforcement provisions. However, there would also need to be a procedure established for regular auditing of each consortium's compliance. Consortia would probably be permitted, to some extent, to set their own rules on reporting, but it may be appropriate to require quarterly statements during initial trial phases to ensure that the approach is working to achieve emissions benefits. Annual reporting of compliance should be a minimum requirement, with a possible "true-up" period that would allow vessels to generate surplus credits, to bank surplus for future years, or to draw down surplus from an existing bank.

3.4.2. Monitoring and Reporting of Emissions

As described in the Introduction, there are a variety of monitoring options that could be undertaken. Ultimately, the selection of a monitoring regime is important in determining the environmental credibility of the approach. This section discusses the monitoring options for both SO₂ and NO_x under a benchmarking regime. We also consider the requirements for location monitoring and reporting.

3.4.2.1. SO₂ emissions monitoring

Monitoring under a consortium approach would almost certainly need to include at least some continuous elements. For larger vessels in particular, on which the potential cost-savings offered by trading are likely to be substantial, it should be appropriate to require a relatively accurate monitoring protocol to be applied.

For SO₂, the required monitoring regime may depend on the control option. Where low sulphur fuels are used, it would be preferable to monitor fuel use via a relatively tamper-proof fuel meter. Alternative methods, including manual sampling or dipping of fuel tanks would be too prone to manipulation to be acceptable to auditors. The fuel use measurements would need to be supplemented by verified receipts showing fuel sulphur content. Consortium members would also need to be willing to submit to random testing of fuel tanks to ensure that the stated sulphur content was accurate. Of course, some ships have several fuel tanks, which may contain different fuel batches (with different sulphur contents), complicating the calculation of SO₂ emissions. Consequently, there needs to be a logged record of which fuel is used at a given time. As an added means of verifying vessel activity, it might be useful to measure engine load levels at regular intervals. These could then be compared to the fuel use information and checked for consistency by a verifier.

For vessels using abatement equipment such as sea-water scrubbing, it would be necessary to establish a monitoring protocol to determine the average emission rate of the abatement equipment. This would need to be done by a qualified third-party environmental audit firm. This emission rate information would then be combined with fuel use information and fuel sulphur content information that is comparable to the information collected for the monitoring of vessels that do not have any abatement technology installed.

As an alternative to these fuel-based approaches, it may be cost-effective for larger vessels to use some form of continuous emissions monitoring. As discussed in the introduction, this would involve sampling the exhaust gas to measure the concentration of SO₂ at regular intervals and also measuring CO₂ concentrations to determine the exhaust flowrate. Again, this could be combined with more direct measurements of fuel use and fuel receipts for the

purposes of verification. CEM probably would be preferable to periodic measurement of scrubber residual emission concentrations, since the sulphur removal rates have been found to vary somewhat, but the robustness and long-term viability of CEM systems in the marine environment has yet to be demonstrated.

3.4.2.2. NO_x emissions monitoring

For consortia covering NO_x emissions, similar considerations apply, but as discussed above, it becomes more important to monitor engine characteristics and emissions concentrations directly because NO_x emissions are not directly proportional to fuel use. Benchmark rates would be set based on engine type with reference to some fixed reduction relative to the IMO NO_x curve, so there would be no need to establish an independent baseline.

3.4.2.3. Position monitoring

In addition to the emissions measurements described, it would also be necessary to measure vessel positions. This would be particularly important for vessels in consortia that cover only a limited geographic region, such as a SECA, or for vessels that enter and exit European waters or the waters relevant for a particular consortium (for example, vessels visiting ports in a certain region or Member State). Position information will also be very important when determining whether to award credit to a vessel for emission reductions that occur within port waters. Because the requirements for sulphur content of fuels used in port are substantially more stringent than the requirements at sea, it is important not to award credits for this activity—or indeed, to count extra debits for vessels that exceed the emission standards for port waters (if such exceedance is permitted as a result of participation in any particular consortium).

Literature sources and those we have interviewed agree that GPS systems can be used to record vessel position with acceptable uncertainty ranges to provide a sufficiently accurate estimate of where and when “covered” emissions arise from a given vessel. Vessels participating in consortium benchmarking should be required to measure and record their position automatically using GPS. This information could then be transmitted electronically to a centralised consortium database (along the lines of what was done in the Demo project), or alternatively could simply be stored and downloaded “by hand” periodically to allow the consortium to keep track of its compliance with its overall target.

3.4.2.4. Reporting

As indicated above, each consortium would need to have a means of keeping track of its continuing progress towards meeting its benchmark targets. This would ensure that any deviation could be communicated quickly to members, who would then have the opportunity to modify behaviours or abatement measures to ensure compliance was achieved. Each member would need to report back to other consortium members, probably via some centralised reporting mechanism and data repository. This could be accomplished via a secure online facility, or through a less automated system. At a minimum, the recorded data should include hourly logs of position, fuel use, measured emission rates, applicable benchmark rate, estimated emissions, and calculated surplus or debits from the “consortium” account.

It is possible that some consortium members would not want their activity details to be made public due to concerns about sharing commercially sensitive information. It is not clear

whether the consortium approach could accommodate these kinds of concerns and still remain transparent enough for members to accept the liability of participation.

3.4.3. Compliance and Enforcement

Compliance for a SO₂ trading consortium would be relatively easy to determine, by calculating the total consortium emissions and total consortium fuel use. Compliance with NO_x trading would be slightly more complicated, because it would involve the “dynamic” calculation of the average benchmark rate based on different vessel types’ activity levels.

One of the key enforcement issues that arises under a benchmarking trading programme but not under a credit-based or command-and-control system is that under benchmarking, some vessels are allowed to “violate” what would otherwise be a firm regulatory requirement. They are allowed to exceed required emission rates because other members of the consortium have voluntarily undertaken additional controls in their stead. This creates a significant problem for authorities seeking to enforce regulatory limits using, for example, surprise inspections. A given vessel found to be in breach of emission limits or fuel-use requirements may be in violation, or it may be a legitimate member of a trading consortium. Governments and other authorities need some way of distinguishing between these two cases. This is another reason that consortium membership would need to be stated well in advance of operation during any particular period.

Vessels would need to carry some form of proof certifying that they were members in good standing of a trading consortium. Otherwise, operators could claim to be part of a consortium when in fact they were not. Enforcement of consortium schemes would also require that there be a way for governments to sanction members of a consortium when the consortium fails to comply with its targets. This may be particularly difficult for marine vessels that can travel internationally. Governments therefore may wish to protect themselves against the possibility of default by requiring some form of deposit or collateral from vessels making only infrequent visits to the relevant waters. An alternative would be for the authorities to hold the entire consortium, including all its members, responsible for “rogue members” activities, which would in turn lead to considerable levels of self-selection and self-policing by consortium members.

3.4.4. Programme Administration

Most of the administrative duties necessary to run a consortium scheme would be handled by the consortia themselves and by third-party verifiers that consortium members would hire. Governments and other authorities would need to develop membership guidelines, vetting protocols, and enforcement regimes to ensure compliance, and would also need to provide guidance on acceptable standards of monitoring and reporting. Authorities would also, of course, need to set the benchmarks against which average emissions would be measured. With this done, consortia should be able to be established.

4. Environmentally Differentiated Charges

This chapter discusses a system of voluntarily differentiated charges on the basis of environmental criteria. The main approach considered is to differentiate existing port dues, though there is also the possibility to introduce separate emissions fees, such as that being considered by the Port of Rotterdam. Port dues are to some extent a special case of more general charging for maritime infrastructure services, an approach currently being considered by the European Commission. The ramifications of a more general system similar to the Swedish system of differentiated fairway dues are therefore also discussed in the text.

This chapter begins with some background on the approach, and then provides a brief discussion of relevant existing programmes. The final two sections discuss the detailed elements of the approach, divided into design and implementation features.

4.1. Background on the Voluntary Port Dues Differentiation Approach

The approach of differentiated port dues would take advantage of the fact that ports already impose charges on vessels that use their facilities. Differentiated charges in this context would involve basing port dues in part on their emissions of pollutants. Such a system can in theory be kept revenue neutral, so that the higher costs incurred on the basis of environmental charges are offset by lower expenses incurred for the use of port facilities and services. The net effect is to increase the cost for high emitters, while environmentally sound ships face lower net costs. We consider here a system in which individual ports differentiate dues on a voluntary basis.

A system of differentiated dues has been used in several Swedish ports since 1998 to encourage reductions in NO_x and SO₂ emissions, and about 25 (or half) of Swedish ports currently offer some form of dues differentiation. As will be discussed in the next section, other countries have developed similar programmes that impose dues differentiated on the basis of environmental criteria.

This section first outlines the existing experience with port dues differentiation programmes. Next, we discuss several design parameters relevant to such programmes, followed by an outline of how they might be implemented in practice.

4.1.1. Differentiation of general infrastructure charges

While port dues are charged throughout the European Union, there is large variation across Member States in the extent to which there are charges for other maritime infrastructure.²⁵ For example, Sweden has a stated policy to apply marginal cost pricing across all maritime infrastructure use and the Swedish Maritime Administration operates a system of fairway dues to this effect. Most Member States generally have lower infrastructure charges; for example, it is estimated that German charges correspond to less than 5 percent of total costs,²⁶ while there are no charges in some Member States.

²⁵ Examples of publicly provided infrastructure services include advisory services, navigation aids, clean-up of pollution, operation and maintenance of equipment, monitoring and maintenance of fairways, emergency towing vessel capacity, etc.

²⁶ GAUSS (2001), p. 32.

Infrastructure based on marginal cost is in line with European Commission recommendations and may become more common in the future. For example, the 1998 Commission White Paper on fair payment for infrastructure use, COM(1998)466 final, recommended that:

“the charging system be based on the “user pays” principle, i.e. all users of transport infrastructure should pay for the costs, including environmental and other external impacts, they impose, at, or as close as possible to the point of use.”²⁷

Similar conclusions were espoused in the 2001 White Paper on European Transport Policy, COM(2001)0370, and form the basis for many of the proposals in the 2003 Directive proposal for charges.

Where charges are in place or brought in, these can form the basis for another possible opportunity for environmental differentiation. Indeed, the Swedish system might function as a model for what other Member States could adopt if they chose to implement port/fairway charges to finance marine services. The Commission could encourage this development by developing emissions indices of environmental performance and recommended differentiation formulas for ports to use.

4.2. Existing Experience with Port Dues Differentiation Programmes

There are numerous examples of port initiatives that have sought to reduce emissions from visiting vessels. These include the initiatives in Sweden (mentioned above), at the Finnish port of Mariehamn, and a discontinued pilot programme at the German port of Hamburg. We also describe one international initiative, the Green Award, which provides a clean shipping certification to vessels that meet certain environmental guidelines, and one initiative in the US state of Alaska.

4.2.1. Swedish Dues Differentiation Programmes

The Swedish system of differentiated port dues was introduced as part of a 1996 agreement between the Swedish Maritime Administration (“SMA”), the Swedish Shipowners Association (“SSA”), and the Swedish Ports Association. In addition to a system of voluntary port dues differentiation, the agreement included a programme of environmentally differentiated fairway dues, administered by the SMA. It also contained provisions for the partial subsidy of the installation of technologies to reduce NO_x emissions, including SCR and HAM.²⁸ All programmes started operation in January 1998. Five years into the programme, 25 out of 52 Swedish ports had introduced some form of environmental differentiation of dues (SMA 2002b). Most large ports participated, including the ports of Gothenburg and Stockholm.

Participating ports differentiate their dues along the environmental classification used by the SMA to differentiate fairway dues, although ports differ in the amount of differentiation they offer. The original 1998 agreement called on ports to offer discounts corresponding to up to one-third of the additional cost of emissions reductions but did not specify how this should be calculated. It also suggested that the differentiation should be revenue neutral, so that lower

²⁷ COM(1998) 466 final

²⁸ These technologies are described in more detail in Chapter 6.

charges offered to low emitters of SO₂ and NO_x are offset by higher charges to those not qualifying for lower fees.

In addition to the voluntary system operated by individual ports, the SMA operates a system of differentiated fairway dues. Fairway dues are charged based on the gross tonnage of the ship as well as cargo weight, and the rebate offered for low emissions form a substantial part of the total amount chargeable. For a typical ship, the difference between full charges and those available to those with highest available environmental rebate correspond to 23 and 56 percentage points for SO₂ emissions and NO_x, respectively.

The SMA estimates that, for the first five years of the combined programme of fairway and port dues differentiation, emissions reduction corresponding to 50,000 tonnes of SO₂ and 27,000 tonnes of NO_x (calculated as NO₂) were achieved in the Baltic Sea and North Sea areas and substantially attributable to the programme (SMA 2002). As Swahn (2002) points out, the calculation is complicated by a number of factors. Both SO₂ and NO_x emissions per unit of transport were on a downward trend prior to the introduction of dues differentiation and the counter-factual baseline of emissions is hard to establish. Also, port dues differentiation was introduced at the same time as fairway dues differentiation and subsidisation of investment in technology to abate NO_x emissions, and disentangling the effects of the different programmes is difficult. Whatever the exact figures, there is substantial agreement in most assessments that dues differentiation has provided important impetus towards emissions reductions. Experience from measurements at individual ports corroborates this. For example, the port of Stockholm registered a drop in NO_x emissions from ferries by 33 percent in the period 1995 to 2001 (SMA 2002a).

4.2.2. Port of Mariehamn

The Finnish port of Mariehamn began offering dues differentiation in 1999 to encourage ships to reduce emissions. The programme, which is similar to the scheme in Swedish ports, was partly in response to the rapid increase in oil tanker activity in the Gulf of Finland over the preceding five years. In order to be eligible for the dues differentiation, ships must receive certification from an official body that they are meeting specific emissions targets. In practice, most participating ships are ferries that run between Sweden and Finland. Most vessels are certified by the Swedish Maritime Administration as part of the Swedish fairway and port dues differentiation programmes.

4.2.3. The Green Award

The Green Award system was launched in 1994 based on an initiative by the Port of Rotterdam. The programme was designed as an incentive for large vessels to increase their attention to safety and environmental protection. Through this scheme, shipowners show their commitment to responsible operation by pledging to observe more stringent safety and environmental requirements than they would otherwise be governed by. The Green Award Foundation, an independent body, grants certification to ships that satisfy the programme's criteria. Over 25 ports and marine service providers offer special discounts on services to holders of Green Awards, and about 165 vessels are now certified.

4.2.4. Port of Hamburg (discontinued pilot project)

The Port of Hamburg ran a pilot project of differentiated dues from July 2001 to June 2003. (The programme has since been discontinued, after the funds used to finance it were

redirected after a change of local government.) Vessels qualified for a six percent discount to port dues if they held an ISO 14000 Environmental Management System certification²⁹ or a Green Award certificate. Vessels were also eligible for a further six percentage point discount (for a total of 12 percent) if they met any of the following requirements:

- § used Tributyltin-free anti-fouling coating;
- § used bunker oil with a sulphur content below 1.5 percent; or
- § demonstrated a NO_x emissions rate 15 percent below the IMO NO_x curve.

The scheme was not revenue neutral, but discounts were paid for from the public budget.

4.2.5. Alaska Cruise Ship Initiative

Since 2000, the Alaska Department of Environmental Conservation (“AKDEC”) has fined ships in Alaskan waters that are found to emit pollutants in excess of standards set by the US EPA. Vessels violating the standards are fined up to \$27,500, depending on how serious the breach is. Originally brought in to address the problem of cruise ship emissions, the rule applies to all marine vessels (including foreign-flagged vessels) operating within three miles of the Alaska coastline.

AKDEC uses vessel smokestack opacity as a proxy for the level of emissions.³⁰ Visible emissions can include SO₂, NO_x, VOC, CO and PM emissions in varying proportions, depending on the characteristics of the engine and fuel used by the vessel. Although opacity levels cannot easily be translated into emissions levels for specific pollutants, opacity levels do correlate with the presence of pollutants, and they have the advantage of being measurable from a remote location (as opposed to onboard). The AKDEC requires that marine vessel smokestacks reduce visibility by no more than 20 percent except when performing specified advanced manoeuvres (such as docking). Monitoring is carried out at major Alaskan ports, and altogether, AKDEC is committed to performing over 250 opacity measurements every year.

AKDEC reports that cruise ship operators in particular have reduced opacity levels by installing cleaner engines and using cleaner fuels since the introduction of the rule.

4.3. Key Design Elements of a Differentiated Port Dues System

This section describes various aspects of the design of a programme of differentiated port dues. First participation by vessels and ports is discussed. After that, the covered pollutants and environmental index used to translate pollution into differentiation criteria are covered. There is also a discussion of the charging structure and level of incentive that a programme can offer. Last in this section, there is a discussion of legal and institutional considerations relevant to designing a system of differentiated port dues.

Much of this discussion would be equally applicable to other infrastructure charges such as fairway dues.

²⁹ This is an international certification for “environmental friendliness.” For more information, visit: http://www.iso.org/iso/en/iso9000-14000/basics/basics14000/basics14000_1.html.

³⁰ A smoke plume’s opacity is the amount of light that is blocked by the plume in the area just above the smokestack.

4.3.1. Determining Participation

The discussions of credit-based and benchmarking programmes have addressed the issues related to which vessels will participate in the scheme. The next section covers that issue for differentiated port dues. The following section addresses a participation element unique to port dues differentiation—which ports will participate.

4.3.1.1. Vessel participation

In principle, a port dues differentiation scheme can include any vessels that would normally pay port dues. There is therefore little need to consider potentially complex factors such as the geographic extent of emissions, vessel flag, or vessel type. This makes this instrument easy to administer. The simplest approach is to make the higher dues payable by high-polluting ships the default charge, and leave the onus on ship operators to demonstrate that they qualify for lower dues. In a sense, vessels would be required to participate in the scheme if they wished to use the port's services. However, emissions reductions would be voluntary.

There may be reasons to leave some classes of ships out of a dues differentiation scheme. One concern would be to avoid “free-riding”, i.e., a situation where ships that have inherently low emissions are awarded by lower dues. In general, however, it is preferable to have the scheme encompass as many vessels as possible. In that case, the scheme can address free-riding by using a more detailed environmental index instead of outright exclusion. The index can be constructed to offer a different level of incentive for certain classes of ships, or use different criteria. These issues are discussed in more detail in Section 4.3.3.2., below.

4.3.1.2. Port participation

In a voluntary system, participation is determined by individual port decisions. Incentives for participation may include factors such as direct environmental concern by the port (or concern about its “environmental image”); the desire to prevent future regulatory action; or the provision of some form of incentive by Government or local/regional authorities. Conversely, differentiation is unlikely where the perceived costs or risks to the port are high.

Perhaps the most significant obstacle to the introduction of a voluntary system of port dues is the fact that ports increasingly operate in a competitive environment. To preserve revenue neutrality, ports would need to offset any incentive offered to low-polluting ships by higher dues for high-polluting ships. This would risk losing the business of high-polluting ships to competitors that do not differentiate their dues according to environmental criteria. At worst, this concern might deter ports from differentiating their dues altogether. Alternatively, it may depress the extent of differentiation to a point where the environmental benefit is compromised.

The potential for loss of business depends on several factors. First, it depends on how important port dues are to the routing decisions of the relevant shipping companies, and on how ship operators therefore would respond to any price changes. For example, regular ferry routes may be integrated into wider transport networks and less likely to be re-routed than some infrequent and ad-hoc cargo transports facing no such constraints. Even for cargo transport, port dues may be of subsidiary importance. One study of German ports indicated that several other factors such as the price of goods at the destination, infrastructure available at the port, accessibility of the port by land and sea, etc. are likely to be more important to routing decisions than port dues (Maennig 2000 cited in GAUSS 2001, p. 5).

At the same time, several port associations have indicated that their members do in fact perceive themselves to operate in a very competitive environment and have a highly price-sensitive customer base. This would leave little room for manoeuvre with respect to the setting of port dues. The response of ships to prices may also differ by vessel class, so that some types of ships respond much more to changes in dues than do others. Where ports are highly specialised and offer services geared towards a particular form of shipping, there may be less pressure on price competition. For example, dedicated tanker ports, ferry ports, or industry specific ports (e.g., for pulp and paper products) may face fewer competitors within a given region.

The loss of business also depends on the behaviour of competitors. In a situation where only a few ports differentiate their dues and significant competitors do not, the risk of losing business is larger. At the other extreme, if all relevant competing ports differentiate their dues on a similar basis, there is scope for each port to operate a revenue-neutral programme with heavy differentiation without fear of loss of business. Such situations may, however, be unstable: there is always a financial incentive for an individual port not to provide any differentiation to win business from high-polluting ships (though this may be somewhat mitigated by the additional local pollution this would lead to). One extreme outcome could occur if only some ports differentiated. If the differentiation encouraged dirtier ships to shift routes away from participating ports rather than reduce emissions, there would be no net environmental improvements. Instead, emissions (and shipping traffic) would just be shifted from participating ports to non-participating ones.

As will be further discussed in Section 4.4.4., these competition concerns may be alleviated to some extent by the central coordination of port participation. Alternatively, as outlined below, dues differentiation could be asymmetric, offering lower charges for low-polluting ships without raising them for high-polluting ones. In this case, competition between ports would not be affected, but some form of public assistance could be required instead to shield ports from financial losses.

It is worth noting that many of the competitive concerns that may arise in a port dues differentiation programme are less problematic with differentiation of publicly managed infrastructure charges, such as fairway dues. In this case, charges are mandatory and set centrally, and can also be harmonised over a large area when this is consistent with charging on the basis of marginal cost.

4.3.2. Covered Pollutants and Incentivised Measures

The degree to which different pollutants and control measures would be covered by the programme is an issue closely related to participation. As an example, the Swedish scheme focuses in particular on emissions of SO₂ and NO_x. In terms of control technologies, the programme explicitly includes technologies that reduce NO_x emissions rates. For SO₂, however, only ships burning low-sulphur fuel are given a discount; ships with scrubbers would not pay reduced port dues. The following two sections address these two issues in the context of the voluntary dues scheme being considered here.

4.3.2.1. Covered pollutants

Like most measures considered here, a dues scheme could cover a variety of pollutants, including SO₂, NO_x, PM, and CO₂. The environmental importance of these pollutants will differ in different regions, and ports have indicated very different priorities when consulted

on the matter. For example, SO₂ emissions are of most importance to ports located in areas that are concerned about acidification. Furthermore, a pollutant like CO₂ is unlikely to be a concern to many ports since its effects are primarily global rather than local.

In general, because the decisions about voluntary dues differentiation schemes would be made by individual ports, each port can address those concerns that are of most relevance in its area. At the same time, as is discussed in Section 4.4.4, there are several reasons why ports may find it useful to coordinate and cooperate when setting up a dues differentiation scheme. This could extend to common permitting, monitoring, and verification procedures, in which case the pollutants covered may also be jointly decided.

In a programme of more general infrastructure charges, the pollutants covered are likely to reflect the concerns of the central government. This may mean that they are less locally differentiated, but also that they more easily can accommodate include national or global environmental objectives.

4.3.2.2. Covered Control Measures

Some emissions abatement measures are unique to port areas, including the use of shore-side electricity (“cold-ironing”) and speed reductions in ports. A port dues system could potentially include any abatement measures that are easily summarised in an environmental index (this is discussed in the next section). The main limitation is the ability of the port to verify emissions during brief stays by ships in port. Verification is likely to have to rely on standardised documentation rather than any measures requiring frequent or continuous monitoring. The situation is similar in the case of differentiated fairway or other infrastructure charges, as monitoring is most easily carried out in port and other instances where documentation is anyway required. In the Swedish system, the SMA maintains a central register of the emissions status of individual ships, and vessels need to register and verify their status in order to qualify for either port or fairway dues differentiation.

In some situations certain control measures might not be as effective in port areas as they are at sea. For example, SCR reduces NO_x most effectively when engines are operating with high exhaust temperatures, which typically involves engines operating at greater than 50 percent load. In port areas, main engine loads are often low (during manoeuvring), which will reduce the reduction efficiency. For start-up the exhaust temperatures are initially so low that no reduction is obtained for perhaps 15 – 30 minutes. While in berth, the main engines are shut off and auxiliary engines are operated, though usually at low loads (at most, 40 - 50 percent). For all of these reasons, SCR may not be an effective technology at reducing NO_x emissions in port. This need not mean that this technology should be excluded from a port dues differentiation programme, as the priorities of the port may include the reduction of emissions also outside the immediate area of the port itself.

4.3.3. Environmental Index and Differentiation Criteria

A key consideration for a port dues differentiation programme is establishing the dues applicable to different vessels—i.e., the nature and extent of the differentiation. In general terms, this involves the construction of an environmental index to summarise the environmental performance implied by a vessel’s operation and characteristics. The general guiding principle is that environmentally beneficial measures should result in an improved index score, with correspondingly lower dues.

An environmental index can generally be separated into two separate components:

1. A measure of the *emissions intensity* implied by a particular vessel characteristic. This can include a number of different factors, such as:
 - A directly measured emissions rate, such as the amount of NO_x emissions per engine kWh;
 - a proxy measure for an emissions rate, such as the sulphur content of bunker oil used by the vessel as an indicator of the SO₂ emissions produced;
 - a technology standard, such as the use of shore power instead of auxiliary engines; or
 - operational measures, such as the reduction of speed in port areas to reduce overall emissions.
2. An index *scaling factor* to translate the emissions intensity into a measure of total environmental impact. Possible factors include:
 - vessel class, such as the distinction between passenger and non-passenger vessels by most Swedish ports;
 - ship size, as measured by gross tonnage or other appropriate measure;
 - engine effect or size; or
 - other measures, such as cargo volume, etc.

By combining an emissions intensity measure and the scaling factor an estimate of a ship's total environmental rating can be constructed.

As described above, a number of dues differentiation programmes are already in operation. These programmes have developed indices to address local environmental concerns. The indices used for differentiated port and fairway dues in Sweden, differentiated tonnage tax in Norway, and the *Green Award* developed in conjunction with the Port of Rotterdam are briefly outlined below. These schemes provide valuable examples of how such a scheme might be structured for a broader EU programme.

4.3.3.1.1. *Swedish differentiated port and fairway dues*

The environmental index used for the Swedish system of differentiated fairway and port dues is developed and maintained by the SMA and based on a combination of NO_x emissions intensity and the use of low-sulphur bunker oil. Both the fairway and port dues systems use gross tonnage ("GT") as the index scaling factor. GT is also the basis on which a portion of fairway dues as well as many Swedish ports' dues are charged, while fairway dues also take into account the cargo volume.

The low-sulphur requirements apply different criteria for passenger and non-passenger vessels. Non-passenger vessels qualify if the bunker oil sulphur content is 1.0 percent or lower. In some cases, further discounting of dues is available if the sulphur content is below 0.5 and 0.2 percent, respectively. Passenger vessels only obtain a discount below the 0.5 and 0.2 percent thresholds. The table below shows the sulphur discounts available at four ports participating in the Swedish system.

Table 5. Examples of port dues differentiation by bunker oil sulphur content

Port	Fuel Type (% S)	Discount (SEK/GT)	Surcharge (SEK/GT)
Gothenburg	>0.5 (ferries)		0.2
	>1.0 (others)		0.2
Helsingborg	≤0.5 (ferries)	0.1	
	≤1.0 (others)	0.1	
Malmö	≤0.5 (ferries)	0.1	
	≤1.0 (others)	0.1	
Stockholm	>0.2 (ferries)		0.2
	>0.5 (ferries)		0.1
	>1.0 (others)		0.2

Source: Port dues schedules of the ports of Gothenburg, Helsingborg, Malmö, and Stockholm.

The table shows that the port of Helsingborg, for example, provides a discount to non-passenger vessels that use fuel with 1.0 percent sulphur or below, while passenger ferries receive a discount of 0.1 SEK/GT if they use fuel with sulphur content 0.5 percent or below. A non-ferry with GT of 1,000 tonnes and using fuel with less than 1 percent sulphur content would receive a 100 SEK discount (around €10). This corresponds to a rebate of 3 percent on the full charge of 3,200 SEK for a non-tanker ship of this size.

The criteria for NO_x emissions are based on the NO_x emissions intensity of ship engines. The full SMA index uses a threshold for dues discounts of an emissions intensity of 10 g NO_x/kWh, with an 11-step linear scale down to zero-emissions intensity. The proportional discount offered is different for passenger ships, cruise ships, oil tankers, and other vessels, with the largest proportional discount offered to cruise and passenger vessels.

Many ports have chosen to use simplified versions of these 11-step scales. For example, the Port of Malmö applies a single category for NO_x emissions below 6.0 g NO_x/kWh, while the Port of Stockholm uses three NO_x categories. The table below presents examples of the discounts available at four Swedish ports, including these two.

Table 6. Examples of port dues differentiation by NO_x emissions rate

Port	Emissions Level (g NO _x /kWh)	Discount (SEK/GT)
Gothenburg	≤ 12	0.05
	≤ 6	0.10
	≤ 2	0.20
Helsingborg	≤ 12	0.01
Malmö	≤ 6	0.15
Stockholm	≤ 10	0.15
	≤ 5	0.25
	≤ 1	0.30

Source: SMA (2004).

For illustration, the differentiation offered by the same four ports is set out in the table below. For example, a 1,000 GT cargo ship qualifying for the NO_x discount (below 6 g/kWh) at the Port of Malmö would pay 150 SEK (around €15) less than a similar ship not qualifying for either the SO₂ or NO_x discounts. This corresponds to a 3 percent discount on the full charge of 4,300 SEK for a non-ferry ship of this size.

4.3.3.1.2. *Norwegian differentiated tonnage tax*

The index system used for the Norwegian programme of differentiated tonnage taxes distinguishes between tanker vessels, dry cargo vessels, passenger vessels, other vessels, and mobile offshore units. Ships are awarded a score based on seven criteria relating to air emissions, emissions to water, and emission accident prevention. There is a heavy emphasis on NO_x and SO₂ emissions, which together contribute up to six of the 10 possible points.

The NO_x emissions criterion is based on the IMO NO_x curve. Mere compliance with the curve gives zero points, but vessels obtain a higher score by lowering their emissions intensity to a proportion of the curve's level. The grading system and points obtainable differs by vessel class.

Sulphur emissions are graded according to the sulphur content of fuel. The scale starts at sulphur content levels below 1.5 percent, with progressively higher scores for lower percentages. Again, the grading system differs by vessel class. For example, passenger vessels obtain a lower score for the same sulphur content than do cargo ships.

The scoring system is used for the differentiation of tonnage taxes payable by all Norwegian vessels with a gross tonnage higher than 1,000. A full score of 10 allows for a 25 percent reduction of the tonnage tax. The average score for covered vessels is 2.33.³¹ Like in the Swedish fairway dues system, the net environmental impact of the programme is hard to calculate because it is difficult to say for sure which reductions are due to the differentiated tonnage scheme.

4.3.3.1.3. *Green Award system*

Under the Green Award System, awards are potentially available for crude oil tankers, product tankers, and bulk carriers with a minimum deadweight of 20,000 tons. Certificates are valid for three years, and the verification of continued compliance with criteria is carried out yearly and is paid for by the ship owner. Currently some 165 vessels have a Green Award Certificate, out of around 3,000 in the potentially eligible vessel worldwide.

The certification criteria include a range of aspects of vessel characteristics and operation, including compliance with selected legislation, specific requirements for crew and management procedures, and some technical vessel specifications. Criteria related to air emissions are not a major component but can contribute a maximum of 10 percent of the total number of ranking points available. The air emissions criteria potentially contributing points towards certification include NO_x emissions intensity of no more than 17 g/kWh; the use of bunker oil with low sulphur content; SO₂ emissions intensity below 6 g SO₂/kWh; and the presence of desulphurisation by water washing during port operations. Several of these overlap with other regulatory requirements and are unlikely to be binding criteria in European waters.

4.3.3.1.4. *Port of Mariehamn*

In the Port of Mariehamn, port dues are discounted by one percent for vessels with NO_x emissions below 10 g NO_x/kWh, increasing linearly to an eight percent discount for an emissions intensity below 1.0 g NO_x/kWh. Similarly, discounts of four and eight percent are

³¹ Mobile offshore units have an average rating of 8.8, cargo ships 2.5, and tankers 2.1

available for ships using bunker oil with sulphur content below 0.5 and 0.1 percent, respectively. A further eight percent discount is available for a combination of NO_x emissions below 1.0 g/kWh (at 75 percent operating capacity) and bunker oil with less than 0.5 percent sulphur.

4.3.3.2. Index design parameters

A number of different design parameters are relevant when constructing an environmental index. There are likely to be tradeoffs between different criteria.

4.3.3.2.1. *Index targeting and coverage*

It may be desirable that the index enables the targeting of economic incentives to those vessels that most require incentives for abatement. One issue to consider is the possibility that some vessels may “free-ride” on a port dues differentiation scheme by qualifying for high scores without any measures taken by the ship operator. For example, it has been noted that some types of ships are naturally low emitters of NO_x and may therefore qualify for low NO_x emissions intensity levels without the need for special abatement activities (e.g., those equipped with gas turbine engines). Similarly, an evaluation of the introduction of fairway and port dues in Sweden estimated that 700 of the 1,100 ships initially registering as users of low-sulphur bunker oil were already using this fuel prior to the announcement of the differentiation programme (MariTerm 1999).

Such situations may or may not constitute a problem. On the one hand, free-riding could undermine the benefit available to ships that do undertake genuine abatement and therefore compromise programme efficiency. On the other hand, there may be situations where it is desirable that benefits of differentiation are available also to ships that qualify anyway. In the Swedish case, it was deemed that many pre-existing low-sulphur vessels had incurred expenses from voluntary agreements and that dues differentiation was an appropriate form of compensation for these past expenses (SMA 2000).

Some free-riding can be eliminated by careful specification of index design. An example is offered by the treatment of NO_x emissions in the Norwegian index. This is based on the IMO NO_x curve, which specifies how high-speed engines can be expected to have a lower NO_x emissions intensity per kWh than do low-speed engines. The Norwegian index addresses this by using the IMO NO_x curve as a baseline and denominating index criteria in terms of a proportion of the associated NO_x curve level rather than an absolute emissions intensity level.

Another consideration is the principles used for the weighting of different measures or characteristics against each other. One approach is suggested by a 1997 Norwegian index proposal to the IMO (MEPC 40/16/2, 1997). This suggests that the index should concentrate on measures that are easy and cheap to effect but which have large environmental benefits. Another approach is to consider only the direct environmental consequences of a particular set of characteristics or measures, without reference to the cost of implementation.

4.3.3.2.2. *Simplicity, transparency, and verifiability*

The index is more likely to be useful if the qualifying requirements are easily established and understood. One way to increase simplicity is to limit the number of criteria and input data requirements, although there may be situations where this comes at the expense of index sophistication. Similarly, relying on factors that are already used in the calculation of port

dues (e.g., using the gross tonnage of ships as scaling factor) may make the estimation of differentiation easier.

It is also important that the index performance of a vessel is externally verifiable with confidence and at reasonable cost. In practise, this may restrict the complexity that can be incorporated into the index.

4.3.3.2.3. *Certainty*

Ship owners are more likely to participate in the programme if the level of benefit obtainable from a measure (e.g., the installation of a certain piece of equipment) is easily calculated and certain.

One aspect of this is to provide certainty over time. It is likely that the index will need revision as technological improvements make new abatement measures available or available at lower cost. For example, the Swedish Maritime Authority lowered the minimum threshold for NO_x emissions from 12 g NO_x/kWh to 10 g NO_x/kWh in January 2005, with the rationale that technological progress had made lower levels of emissions feasible. At the time of writing, the Port of Stockholm has reflected this in its dues differentiation scheme, while some ports have chosen not to do so yet. Similarly, the index limits for the sulphur content of certain fuels were changed as the provisions of Directive 1999/32/EC entered into force and explicitly prohibited the use of some high-sulphur fuels in Swedish waters.

Such revisions are likely to be necessary to maintain index efficiency, but they need to be weighed against the possibility that frequent changes may undermine the incentive provided for abatement. One of the rationales for port dues differentiation is that it encourages investment in abatement by enabling ship operators to recoup the expenses associated with abatement through the payment of lower port dues in the future. This calculation is upset if subsequent index revisions make a ship ineligible for lower dues. Further, even the *expectation* of index revisions may cause operators to be wary of additional expenses associated with emissions abatement.

One way to alleviate these concerns is to make certification valid for a longer period of time, subject to continued compliance with the *original* (rather than any updated) criteria. This is the model employed by the Green Award index, where certifications are valid for three years, regardless of any modifications to the criteria for new certifications. This provides operators with some protection of their investments in index compliance.

4.3.3.2.4. *Flexibility*

It is generally desirable that indices put as few restrictions as possible on qualifying abatement options. For example, NO_x abatement can be achieved through a range of options, including optimised ship engine (re-)design, specific catalytic reduction, use of fuel additives and emulsions, humid air motor technology, speed reductions, etc. Insofar as the aim is to reward with a high score the reduction of NO_x emissions, the index should ideally make allowance for all of these technologies. In practice, most existing indices have opted to use a measured emissions rate instead of specifying particular qualifying technologies. This has the advantage of enabling the ship operator to identify and use the cheapest technology available.

Similar approaches are desirable for other pollutants, such as PM or SO₂, although the exclusive reference to fuel sulphur content in current indices is likely to be a reflection of the unavailability in practise of other forms of abatement of SO₂ emissions. In addition, the use

of low-sulphur fuels offers relatively easy monitoring by the inspection of fuel purchase receipts. Detailed provisions for too large a range of abatement options may bring the specification of the index in conflict with the objectives of simplicity, transparency, and verifiability.

4.3.3.3. Index scaling factor

The scaling factor used should ideally provide a reflection of how the emissions intensity of the ship translates into absolute environmental impact. For example, a larger ship is likely to use more bunker oil, and the environmental benefit/damage (in the form of lower/higher SO₂ emissions) of low/high-sulphur bunker oil is therefore likely to be larger. The following categories outline some of the options that may be considered.

Vessel size. Both the Swedish and Norwegian programmes use gross tonnage to differentiate dues and taxes, respectively. This was chosen partly on the grounds that both port dues and Norwegian tonnage taxes tend to be determined by gross tonnage, and the differentiation therefore translates into a straightforward discount on existing charges. There are several other potential measures of vessel size, such as the amount of cargo carried or ship dimensions.

Vessel engine characteristics. Some ports have indicated that they do not consider vessel size a good scaling factor but suggest instead the use of engine effect (in kW). This is consistent with the measure of NO_x emissions in grams per kWh, which is the unit used by the IMO NO_x curve and several existing indices. By using the IMO NO_x curve, the Norwegian tonnage tax index implicitly distinguishes between vessels' engine speeds. Another option for engine categorisation is the size of ship engines as measured by their displacement. This was advocated by the European Association of Internal Combustion Engine Manufacturers (2002) in a consultation response on engine standards, partly with the motivation that it is a characteristic that is easily ascertained and not likely to be easily modified.

Local conditions may be of relevance when determining the scaling factor. For example, ships operating in icy waters are likely to require more powerful engines. In these circumstances an index based on engine size may be thought to unduly penalise local vessels requiring such engines over temporary visitors that do not. This is especially so as the operation of vessels with ice-breaking capacity contributes to the maintenance of fairways.

Vessel class. Both the Swedish and Norwegian systems use different vessel classes to construct the index. For example, both systems place higher requirements on passenger ships than on other vessel classes, largely to reflect the fact that many passenger ships already have switched to operation that results in lower pollution.

Vessel route. One possibility is also to include the consideration of vessel route when considering dues differentiation. A motivation for this might be to offer a higher weighting to emissions reductions near the port or other relevant area. In practice, this approach has several complications, including the monitoring of location, and the possibility of providing incentives for ships to make sub-optimal routing decisions. Overall, the inclusion of vessel route in the index is likely to complicate index calculations substantially.

4.3.4. Charging Structure and Level of Incentive Offered

Many emissions abatement measures require significant one-time investments. By contrast, port dues are payable in smaller amounts but over a longer time horizon. Calculating the

incentive provided is therefore often a matter of comparing current expenditures on abatement with (discounted) dues reductions in the future.

It is important to note that the level of incentive faced by the ship operator generally depends not on the actions by any one individual port, but on the dues structure of *all* of the ports it visits. It is also complicated by the fact that much of the total cost of visiting a port is in the form of charges for services that may not be run directly by the port itself. For these reasons, calculating the average level of incentive faced by a ship operator from any one port’s actions is very intricate, and the decision by the port about what charging structure and level of incentive to offer similarly complicated. Much of this discussion is handled in later sections, and the discussion below is mainly in general terms.

4.3.4.1. Typical types of charges levied by ports

The table below provides an overview of categories of typical charges in European ports. Not all of these charges are applicable to all ports and all vessels. For example, several ports make no separation of port and quay dues, and pilotage and towing assistance are only compulsory for certain classes of vessels.

Table 7. Typical Types of Charges Incurred by Ships Accessing Ports

Category of dues	Determinants of Charges	Function
Port dues	Size/dimensions of ship Type of ship Shipping route	Port administration and water-side part of port infrastructure
Quay dues (tonnage dues, wharfage charges, landing fee, shore fees, etc.)	Cargo type, Cargo volume/weight, Shipping route	Quay-side services and land-side infrastructure, port administration
Pilotage and towing (pilot dues, towing dues, fairway dues, etc.)	Size/dimensions of ship Type of ship Shipping route	Fairway and security infrastructure

In addition to these charges, ships potentially also incur charges for a number of additional services and facilities when accessing ports. These may include:

- § berth hire / dockage;
- § berthing/unberthing, mooring/unmooring;
- § stevedoring, wharf-handling, cargo receiving/delivery;
- § cargo processing;
- § transit storage;
- § warehousing;
- § equipment hire;
- § fuel; and
- § other miscellaneous utilities (water, waste disposal, shore power, etc.).

The charging structure and extent of differentiation offered by a particular port will depend on the level and nature of the dues that are already in place. Most European ports have some form of port dues, but they vary significantly to reflect other advantages to customers of accessing a particular port (e.g., geographic proximity, or availability of certain

infrastructure). The original tripartite agreement that launched the Swedish port dues differentiation programme recommended that one third of the additional cost of emissions reductions be covered by port dues differentiation (SPSA 1996). The agreement did not specify how this was to be calculated, and participation is in any case voluntary.

Many port services are offered not by the port authority itself, but by private companies operating within the port and offering pilotage, stevedoring, equipment hire, etc. These are therefore not always under the port's control, and therefore not suitable for inclusion in a port dues differentiation programme. Instead, dues differentiation is generally best limited to pure infrastructure charges such as port and quay dues.

There are also limits to the incentives that can be provided for certain vessel classes. A study of the charging structure in five ports in northern Germany found that port and quay dues constitute no more than 20-30 percent of the total port costs for most ships, even when the costs of cargo handling are excluded. Reasons for this include small vessels' exemption from pilotage and tugboat requirements, and special tariffs for short regular users on short-sea shipping tariffs. For some vessel classes, port and quay dues constituted no more than 2 percent of non-cargo handling port expenses. The net effect of this might be that even very large discounts to port dues of small ships are unable to offer incentives that constitute a significant proportion of total cost of emissions abatement measures (GAUSS 2001).

4.3.4.2. Revenue neutral port differentiation

An important potential stumbling block to the introduction of a port dues scheme would be a perception by ports that it would be disadvantageous to deviate from the setting of prices on strictly commercial grounds. In theory, port dues differentiation can be constructed to be revenue neutral, offsetting the lower charges for ships with a high environmental index score with higher charges for ones with low scores. As long as the traffic flow does not change, the port could therefore offer a degree of incentive for emissions abatement without incurring significant costs (beyond added administration costs). The exact charging structure and differentiation criteria required to achieve this will differ from port to port, as the composition of traffic varies significantly between ports.

In practise, ports may find it difficult to preserve revenue neutrality. Some ships that pay higher charges after the introduction of a scheme may choose to access other ports. (Conversely, it is possible that a larger number of low-polluting ships choose to access a port with the differentiation scheme). Such changes in the pattern of traffic to the port could result in lower average dues and lower total revenues. In general, the more price-sensitive the customers of a port, the more difficult it will be to preserve revenue neutrality with a port dues differentiation scheme. There is indication that some Swedish ports registered revenue losses when dues differentiation was first introduced (Lemieszewski 1998 cited in BMT 2000, Appendix 3, p. 11).

Note, however, that the precise effects are likely to be complex. The revenue effects of changes in traffic will depend not only on the changes in absolute volume of traffic, but also on how the profitability of different traffic segments correlates with any changes in composition. These are determined by local conditions. As discussed above, the effects also depend on potential competitor ports' decisions with respect to dues differentiation. Either way, competition between ports is likely to provide an effective upper limit to the extent of feasible differentiation.

In situations where ports are publicly owned and regulated these concerns may be more easily addressed. A public authority could co-ordinate the introduction of a port dues differentiation scheme on national or regional level, similar to the Swedish fairway dues system. If similar conditions could obtain in all relevant ports, the risk of distorting traffic flows is smaller, and revenue neutrality easier to obtain. This would be limited by competition from ports outside public control, notably in other countries, which would still be a concern. In the case of public ownership, it could also be decided that any negative commercial effects on ports could be a reasonable trade-off against emissions reductions.

4.3.4.3. Publicly incentivised port dues differentiation

If the concern about potential revenue loss by ports is sufficiently strong to prevent the emergence of dues differentiation it may be necessary to provide some public incentive to bring about port dues differentiation. An incentive in the form of public subsidy was used in Hamburg, where the City of Hamburg provided the funds for “bonuses” to low-polluting ships. No extra charges were made to high-polluting vessels, and the City paid for all of the extra cost of the differentiation scheme. A subsidy could also be partial, complementing rather than replacing the revenue-neutral model.

The opposite model could also be used, imposing surcharges on high-polluting vessels. This would be similar to the Alaskan scheme, where ships with a certain level of emissions (as measured by smoke-stack opacity) are fined. In the context of ports, public authorities could charge ports directly for the visit of high-polluting vessels.³² The scheme would not be wholly voluntary, in that ports would be required to report the emissions profile of its visiting ships to public authorities. However, such reporting regulations are already in place in some locations. Also, the scheme is voluntary in the sense that the port could choose not to pass on costs directly (e.g., if a particularly important customer segment were very price sensitive and had an option to visit a port that did not have the surcharge imposed). Nonetheless, the programme would provide ports with the right incentives, as the marginal cost of providing services to ships depends on the emissions profile of the ship. In a competitive market, port dues differentiation is therefore optimal in the same sense as marginal cost pricing.

The need for public incentives will differ from port to port. The Swedish example shows that a voluntary scheme with broad uptake can operate successfully for a prolonged period of time. A likely reason for the success of this scheme is the participation by a high proportion of Swedish ports, which helps mitigate the risk of loss of business by any one port.

It also is worth noting that the use of public money is not an effective substitute for coordinated introduction of port dues differentiation. In Hamburg, it was concluded that the scheme was unlikely to offer significant environmental benefit in the absence of similar schemes in other ports. The subsidy was therefore felt to be an ineffective use of public money, which contributed to the decision to discontinue the differentiation scheme. This illustrates that schemes relying on public subsidy carry some inherent uncertainty. As with all other uncertainty, this has the potential to decrease the effectiveness of the scheme, as ship operators may feel less certain that the cost of initial investment in emissions abatement can be recouped later.

³² Another option would be for the authorities to impose the surcharge on vessels directly. In this case the programme would no longer be a port dues differentiation scheme but resemble instead the Norwegian environmentally differentiated tonnage tax and other environmental taxes.

4.3.4.4. Specially negotiated port dues and commercial sensitivity of port dues

Another important complicating factor is that many ports charge regular customers specially negotiated rates that differ from published port tariffs. These rates are normally not public information, but consulted ports indicate that the difference from published rates may be substantial.

The port can of course decide to take into account an environmental index when negotiating any special dues. However, the incentive for abatement is nonetheless much weakened by the lack of transparency and certainty. Ship operators have much less certainty *ex ante* that they will recoup the costs of emissions abatement measures. Also, even where ports have a stated policy of dues differentiation, it is not clear that the ship operator can verify *ex post* the extent to which low-emissions operation has given them any benefit. This will be clear to operator prior to undertaking any emissions abatement, which undermines the effectiveness of dues differentiation even where ports intend to carry it out.

It is hard to see how this can be addressed in a commercial setting. There is no credible way for ports to “ earmark ” certain payments as differentiation, as the negotiation position of the port will be determined by the total amount payable by the operator.

Also, ports may consider information about negotiated dues commercially sensitive and not want to make it public. Apart from the difficulties that arise in ensuring effective differentiation in the negotiation between ships and the port, this would also limit the extent to which public incentives can contribute to a voluntary dues differentiation programme. The problem stems from the fact that the authority cannot verify the dues charged, and whether its subsidy results in effective differentiation. To some extent, the port has an incentive to pass on the subsidy it gets to the ships, as it is able to offer more competitive bids if it does so. However, the exact rate of pass-through is not easily determined, and there is also the limitation that the incentive cannot be set in proportion to the dues, for the simple reason that the dues are not known.

4.3.4.5. General infrastructure charging

Many of the above concerns do not arise in the case of publicly managed infrastructure charges, such as the Norwegian tonnage tax or Swedish fairway dues. The question of revenue neutrality is more easily addressed when charges are equal across a large jurisdiction. In addition, there is an argument on the grounds of economic efficiency to set public charges to that they reflect total social costs, including environmental concerns. More specifically, a system of prices based on marginal cost could be defined to include total marginal cost, including any environmental externalities.³³ Several other complicated issues that arise in the context of voluntary port dues would also not arise, including potentially problems arising from specially negotiated and potentially confidential tariffs, as well as the need for public incentives.

³³ Marginal costs are those variable costs that reflect the cost of an additional vessel or transport unit using the infrastructure. At a minimum they included the variable cost of operating and maintaining infrastructure, but may also included environmental costs as well as other aspects (e.g., indirect costs due to increased accident risk). This position is embodied in the 2001 White Paper (EC 2001), which states that: “[t]he fundamental principle of infrastructure charging is that the charge for using infrastructure must cover not only infrastructure costs, but also external costs, that is, costs connected with accidents, air pollution, noise and congestion.”

4.3.5. Legal and Institutional Considerations

One of the attractions of a voluntary port dues differentiation scheme is that it generally does not require new institutions. Most European ports are free to determine their own dues and therefore also free to introduce dues differentiation. Indeed, dues are already commonly differentiated according to vessel class or particular vessel characteristics. The addition of environmental criteria is not likely to require new institutions.

This is provided that ports can easily verify the status of ships with respect to the differentiation criteria it has in place. In the absence of existing institutions to carry out certification of ships according to the desired criteria, this may require that procedures be put in place. This is discussed further below.

In countries where port charges are publicly managed a coordinated institutional set-up is possible and may be necessary. For example, port charges in Italy are centralised in the form of taxes (anchorage tax, state tax, and port tax), all of which are centrally set by the state. Fifty percent of the port tax accrues to the port, and the port is thus not free to set its own charges. In this case, a differentiation scheme could be centrally administered by the state. This is a special case of the more general principle of differentiating centrally administered infrastructure charges.

As is discussed further below, there are significant advantages to setting up a port dues differentiation scheme in several ports simultaneously. However, there may be situations where such coordination of dues among ports raises concerns about anti-competitive behaviour. If so, coordination may be subject to challenges under EU or national competition law. The Swedish system appears not to have encountered any such legal obstacles, which may be an indication that this is not a significant concern. Nonetheless, clarifying this point would provide assurances to individual ports and to member states that are considering measures to encourage port dues differentiation in their jurisdictions.

4.4. Key Implementation Elements of a Differentiated Charging Scheme

This section describes various aspects that would be involved in implementing a programme of differentiated port dues, with some additional remarks on the implications for the differentiation of more general infrastructure charges.

4.4.1. Permitting and Verification of Differentiation Eligibility

For a dues differentiation scheme to function reliably, it is important that ports are able to ascertain whether a particular ship conforms to the differentiation criteria specified in the environmental index used.

Ships are normally required to provide certificates for a number of different aspects of ship operation, e.g., suitability for passenger transport, safety standards, personnel training, etc. Existing environmental regulations also require some certification, mostly to demonstrate compliance with MARPOL regulations. Verification of compliance is normally carried out by national authorities, or by private companies on their behalf.

In the case of a port dues differentiation scheme, additional verification is likely to be necessary. This is because the standards of an effective environmental index may not normally be reliably monitored. Member States can encourage the emergence of port dues differentiation by carrying out a certification programme that can be used for environmental indices used by ports. This is done in the Swedish scheme, where the SMA carries out

certification of ships' NO_x emissions rate and use of low-sulphur bunker fuel. Ship operators wishing to obtain a certificate are required to file an application with the SMA and also to pay for the certification procedure. The SMA also maintains a central registry so that ports (or the public, generally) can check whether a particular ship fulfils certain criteria. SMA certificates are also used by the Port of Mariehamn. In principle, national authorities can therefore help encourage the emergence of port dues differentiation even without enacting any differentiation of infrastructure charging itself.

In the absence of certification by national authorities, there are private certification bodies that already carry out ship certification of various forms. Ports could rely on these instead, and should make clear to operators which certification procedures are valid for the dues differentiation scheme they operate.

Note that a centralised certification system does not mean that identical differentiation criteria have to be used by each port. In the Swedish scheme, ships' certificates state the NO_x emissions rate and the sulphur content of the fuel used, but as indicated above ports use these to form their own indices. For example, the NO_x limits used and amount of discount/surcharge on dues differ between ports. Some ports offer no differentiation on the basis of NO_x emissions but nonetheless reward low SO₂ emissions. There is therefore scope for some flexibility even if ports rely on a single, centralised certification procedure to determine eligibility in their separate differentiation schemes.

Another certification variety is that offered by the Green Award Foundation, whose primary purpose is to offer certification that helps ports reward environmentally sound and safe operation. As it does not have detailed provisions for emissions to air, and offers certification as part of a "package" of several other measures, it may not serve the purposes of individual ports. However, as a pre-existing standard, it could facilitate the development of a standard certification scheme and reduce the cost.

The cost of certification may be substantial in some cases, and it is important to bear this in mind when constructing the environmental index used. A high cost of certification may deter participation, or alternatively diminish the incentive for abatement as it would reduce the effective reward for lower emissions.

As mentioned above, there may be a benefit to allowing certificates to be valid over a time horizon of several years, even if the certification criteria or environmental index change in the intervening period. This helps provide ship operators with certainty that their initial outlay on investment in emissions abatement and certification can be recouped in future years.

4.4.2. Monitoring and Reporting

After initial certification, a monitoring regime is likely to be necessary to ensure that ships continue emitting at the low emissions levels for which they were originally certified. This is particularly important where the maintenance of continued low emissions is costly and operators therefore have an incentive to abandon controls. For example, shipowners must continually purchase urea to keep SCR running, giving operators an incentive to turn it off when not monitored. In contrast, HAM technology actually improves engine performance, so once installed on the ship, operator's incentives are aligned with the objectives of the port dues differentiation scheme.

There are various forms of monitoring, including spot checks, continuous documentation (e.g., of fuel purchases), and technical reporting equipment on ships. These technologies are discussed in more depth in Chapter 1 and in the discussion of monitoring for the credit-based approach. As with initial certification, both participation and abatement are discouraged if the cost to ship operators of monitoring and reporting are too high.

In general, ports have limited resources to engage in their own monitoring, and will need a form of external documentation of monitoring. The reporting procedure can be easy provided documentation is available, as the ship can simply provide it upon entry to the port. As with verification, it is probably sensible to employ an approach similar to the Swedish system, where monitoring is centralised.

Ports participating in the Swedish programme rely on the SMA's certification and monitoring of emissions levels. Certificates of NO_x emissions levels are based on initial verification procedures followed by intended subsequent spot-checks of ships and re-certification after three years. Sulphur levels of fuel are verified based on continuous submissions of fuel purchases, with the requirement that qualifying ships use qualifying fuels permanently. In 2003, around 1,300 ships had been certified for the low-sulphur requirement, of which an estimated 700 had been using qualifying low-sulphur oil prior to the introduction of dues differentiation (MariTerm 1999 and SMA 2003). Some 30 ships had NO_x emissions below the 12 g/kWh threshold.

4.4.3. Compliance and Enforcement

The issue of enforcement in a voluntary port dues programme is closely related to monitoring. Port authorities—or the broader certifying body—would need some way of penalising ships if they were deemed not to be reducing emissions in the manner agreed to. For example, if a ship were receiving port dues discounts based on certification for burning low-sulphur fuels and authorities discovered that the ship was not burning the fuels for which it was certified, a penalty would need to be levied against the shipowner. As noted in the discussion of the credit-based approach, the level at which the penalty is set can play an important role in deterring cheating. In principle, penalties should be set at a level well above the cost savings that shipowners would obtain from cheating in order to create strong disincentives to cheat.³⁴ In practice, the most important issue may be ensuring that shipowners are aware of the steep penalties for cheating.

The ability of ports to enforce high penalties may be limited in practice, especially where competition is strong. For an example, several Swedish ports limit their penalties to the forfeiture of any future discounts, which is likely to reflect the inability to take much further action. On the other hand, the SMA has various penalty procedures in place to ensure proper safety and other certification of ships entering the waters for which it has responsibility, and environmental certification is carried out in this context. As with many other aspects of a programme of voluntary port dues differentiation, the enforcement of its provisions can be greatly helped by assistance from public authorities.

³⁴ Note that shipowners are also likely to account for the likelihood of being caught in determining whether to cheat. In theory, the penalties should be greater than the probability of being caught multiplied by the savings from cheating.

4.4.4. Programme Administration

A voluntary system of port dues need not necessarily have any form of central coordination. Indeed, the vessel participation, covered pollutants, differentiation criteria, and charging structure could all be left to the individual port, reflecting local concerns as appropriate. The decentralised nature of the approach is part of its appeal, as ports can choose their dues differentiation elements to reflect local concerns. For example, NO_x pollution is an important concern in some ports, while emissions of PM are more important in other areas; ports may be specialised (e.g., tanker ports, ferry ports) and therefore choose to introduce differentiation only for some class of vessel; ports may have different tariffs and therefore differing bases for differentiation; etc.

At the same time, there are several reasons why the piecemeal introduction of port dues differentiation may be unlikely. First, as discussed above, the incentives for the introduction of dues differentiation by one port are heavily influenced by the actions of its competitors. The more certainty can be provided that a port's competitors are taking similar measures, the more likely is the participation of that port too.

Second, the pollution reduction and cost saving benefits of port dues differentiation depends very heavily on the number of ports participating. This is because many abatement measures require significant expense by the ship operator, and often with a large proportion in the form of an initial investment outlay (e.g., the installation of SCR or HAM catalytic equipment, or the re-engineering of ship engines). Differentiation by a single port or small number of the potentially relevant ports may therefore be unable to bring about significant abatement. This perceived absence of such a "critical mass" has been cited as one of the reasons for the demise of the Port of Hamburg's system of dues differentiation. Without similar measures by other ports, the environmental benefit was felt to be too low to justify the cost of financing lower port dues from public funds.

Third, there are some fixed and administrative costs of a port dues differentiation scheme that can usefully be best pooled between ports. Notably, there is a cost associated with the additional certification required to determine the emissions standard of a ship. Again, in the case of the Port of Hamburg, it was calculated that the differentiation of dues offered by the Port of Hamburg alone was insufficient in many cases even to cover a ship's cost of environmental certification (let alone the abatement of emissions). The Swedish system overcame some difficulties by the fact that the Swedish Maritime Administration maintains a central register of ships that have demonstrated that they are low-polluting. Coordination to ensure that certification is valid across ports is likely to help mitigate such problems.

In sum, a degree of coordination is likely to be important to the success of voluntary port dues differentiation. The Swedish 1996 agreement was negotiated with the Swedish Ports' and Stevedores' Association, which then made a recommendation to their members to participate. The continuation and indeed expansion of the Swedish system is probably explainable in part because many ports participated from the outset, including many of the largest ports. Similar port association agreements are likely to help in other Member States as well. (Where ports are publicly owned or regulated, coordination is naturally easier). Of course, the caveats about the legality of coordinated action by ports need to be borne in mind.

5. Environmental Subsidy Approach

5.1. Background on the Environmental Subsidy Approach

Environmental subsidies involve financial support by the government of environmentally desirable activities. The support can come in the form of grants, low-interest loans, favourable tax treatment, and other financial assistance to for products with desirable environmental characteristics. Support can also be linked directly to emission reductions, in which case the subsidy programme would resemble a credit-based programme. We begin with background on the state aid guidelines and contrasts among various types of environmental subsidies.

Environmental subsidies can take various forms and levels, with different implications for the potential environmental gains that might be generated. A subsidy programme could allow ship owners to receive funding for the installation of emission control equipment and, in some cases, for the operating costs associated with emission reductions. However, unless the subsidy were equal to or greater than the full cost of installing and operating emission control—including the net effect of any operating cost savings—providing a subsidy would not by itself induce companies to invest in emission control. Subsidies typically have not been so generous. Thus, while subsidies would reduce the financial burden to firms of investment in pollution control, they generally would not themselves provide positive incentives to pursue pollution control. Moreover, government subsidies would not necessarily lower the overall cost of reducing emissions if they did not target the most cost-effective controls. Subsidising particular control actions could raise the overall social cost if the activity subsidised (e.g., investment in a particular control technology) were not the least-cost means of reducing emissions. For all these reasons, subsidies should probably be considered financing mechanisms that operate as adjuncts to mandatory emission control programmes rather than stand-alone emission reduction programmes.

An exception to this general characterisation of an environmental subsidy programme is the case in which ship owners would receive payments directly for emission reductions at amounts sufficient to compensate for the costs of the reductions. As noted below, there is one example in the South Coast (Los Angeles) in which a subsidy is paid to reduce emissions rather than to assist in financing emission control equipment required by other environmental provisions. Even in this case, however, the subsidy programme is tied to other emission reduction requirements.

The following section provides a brief overview of some experience with environmental subsidies, including the Los Angeles programme that provides subsidies for emission reductions. We then consider the various design and implementation issues involved in developing subsidy programmes for shipping emissions, both as financing adjuncts to mandatory programmes and as stand-alone programmes.

5.2. Existing Experience with Environmental Subsidy Programmes

This section provides a brief summary of various environmental subsidy programmes. We distinguish between environmental subsidies as supplements to other programmes and environmental subsidies as stand-alone programmes to provide environmental benefits. Supplementary subsidy programmes are much more prevalent.

5.2.1. Subsidies as Supplements to Other Programmes

Many programmes provide subsidies of various sorts to encourage environmentally friendly efforts. There are, for example, numerous programmes to subsidise the development and implementation of “clean coal” and renewable energy projects. These programmes take the form of direct payments, tax abatements, loan guarantees and other means of reducing the costs to firms of reducing emissions from their facilities. One approach is to offer a premium price upon initial investment, which was done in the UK 1990-1998 Non-Fossil Fuel Obligation tendering system for investment in renewable energy. Another potential approach is to decrease the risks associated with investment. Investment tax credits and loan guarantees have been provided in a number of EU countries. Some of these approaches may be transferable to ship operation or shipbuilding. The closest parallel to renewable energy may be in the construction of new ships.

Of most direct relevance is the programme developed in Sweden to subsidise the cost of installing pollution control equipment. Specifically, the Swedish programme provided a subsidy equal to 40 percent of the cost of installing SCR/HAM equipment. The programme was part of a tripartite agreement between the Swedish Maritime Administration, the Swedish Shipowners Association, and the Swedish Ports and Stevedores Association in 1996 to take measures to reduce emissions of SO₂ and NO_x from ships by 75 percent over the course of five years. The chief outcome was a system of differentiation of fairway and port dues along environmental criteria. In the case of NO_x reductions, however, it was deemed that the investment in SCR catalytic equipment was too expensive to be fully incentivised by these measures. The SMA therefore agreed to reimburse ship operators the full fairway dues paid over a five-year period if they installed SCR or HAM catalytic equipment. The restitution was capped at 40 percent of the original investment cost, decreasing to 30 percent in 2001, and no further subsidy from 2002 onward. The SMA reports that uptake was good, with a number of ships installing the eligible equipment. One reason for this may be that the 40 percent rule provided ship operators with some certainty about the benefit and extent of the subsidy, decreasing the risk taken when investing in emissions abatement. Because the programme relied on exemption from pre-existing infrastructure charges, it was relatively easy to administer.

In a pilot programme in 2000-2002, the port of Hamburg provided funds to provide lower port dues to ships meeting certain low-polluting criteria. Specifically, ships using low-sulphur bunker oil, having tributyltin-free anti-fouling paint, or demonstrating a NO_x emissions rate 15 percent below the one specified by the IMO NO_x curve were eligible for a 12 percent discount on port dues. A lower discount of six percent was available for ships meeting certain environmental management standards (holding a Green Award or ISO 14000 EMS certificate). Like the Swedish programme, the Hamburg subsidy programme used public money to provide exemption from pre-existing charges. It also has in common the approach to supplement environmental requirements rather than provide a sufficient independent incentive for ship owners to undertake costly emission controls. The Hamburg programme has been discontinued, partly because it was felt that, in the absence of similar measures by other ports and cities, the measure was unlikely to provide sufficient incentive to undertake expensive abatement.

Note that there are some situations in which subsidies might be recommended to avoid unintended adverse air emissions effects. One example concerns the energy taxation of electricity used by ships in ports. Current EU legislation on energy taxation (Directive

2003/96) requires that Member States exempt electricity produced on board a craft from taxation. In contrast, electricity produced on land is subject to taxation. Thus, ships would be discouraged from using shore-side electricity even though, as noted above, air emissions would be reduced. This unintended effect could be avoided by providing energy tax exemptions for ships using shore-side electricity in ports. Individual Member States can in fact apply for such an exemption on environmental grounds, and the Commission is now considering the possibility of introducing this exemption on an EU-wide basis.

An environmental subsidy programme could be incorporated into the existing subsidies provided to EU shipbuilders by making the subsidy contingent on incorporation of air emission control equipment. Current rules authorise European governments to provide a subsidy of up to 14 percent of the contract value of ships in “protected market segments”, as long as the mechanism does not distort competition among EU shipyards. To avoid such distortions, aid above six percent must be approved by the EC, which would only authorise the aid if it were the minimum necessary to keep the contract within the EU. At the moment, a temporary across-the-board subsidy of six percent is allowed pending outcome of a World Trade Organization case against South Korea.

Shipbuilding subsidies could be transformed into environmental subsidy programmes in several ways:

- § Part of the subsidy could be targeted for pollution control equipment.
- § The subsidy could be conditioned on installing pollution control equipment.
- § The subsidy could be conditioned on achieving a given emission rate.

It is important to note, however, that making any of these modifications in the absence of a specific environmental requirement would in effect reduce the net gain to the shipbuilder. Thus, incorporating an environmental requirement would compromise the objectives of the subsidy (i.e., to provide financial support to EU shipbuilding). If environmental regulations required the installation of the subsidised pollution control equipment, however, the subsidy objectives would not be compromised; but in this case, the subsidy would not have an independent environmental effect. Indeed, as noted above, subsidies generally have the effect of reducing the net cost to regulated firms of environmental requirements rather than of providing independent emission reductions.

5.2.2. Subsidy as a Stand-Alone Programme

The subsidy programme developed in the South Coast (Los Angeles) region provides a contrast to the traditional environmental subsidy programme because it does provide an independent incentive for firms to implement costly emission control. This programme—named the Air Quality Investment Programme (“AQIP”)—is similar to the credit-based programme discussed above, except that instead of receiving RECLAIM Trading Credits, a participant in the subsidy programme receives money for reducing emissions. The fund is administered by the local air quality agency (South Coast Air Quality Management District), which determines which projects receive subsidy funds. Note, however, that the subsidy funds ultimately are provided by companies that pay into the AQIP in lieu of being required to implement trip reduction strategies to achieve emission reductions. Thus, the government is really functioning as a “middleman” between the companies that require emission reductions and the companies that propose projects to achieve emission reductions.

5.3. EC Initiatives as Potential Environmental Subsidy Programs

The EC Directorate-General for Energy and Transport has established several programmes that could lend themselves well to the incorporation of environmental subsidies. The Marco Polo programme, begun in 2003, seeks to relieve congestion on European motorways and reduce pollution in nearby areas by funding short-term projects that promote the transport of freight by light rail, inland waters, and the open sea (EC 2004). Road freight has grown rapidly in the last decade, especially in the ten newest Member States, and the aim of this programme is to effect a “modal shift,” i.e., a reversal of this trend and a rise in the use of other modes of freight transport relative to roads. The first Marco Polo programme, with a budget of €100 million for funding thirteen projects, expires in 2006. It will be superseded by Marco Polo II (2007-2013), for which a budget of €740 million has been proposed for supporting fifty projects. Many of the projects funded have been upgrades to existing port terminals or have funded the establishment of short-sea shipping services between European ports. The adoption of additional air emissions provisions in the funding criteria of the Marco Polo programme, in effect incorporating an environmentally differentiated subsidy into the programme, could provide further benefit beyond those offered by the modal shift by ensuring that marine transport itself is also made cleaner. For example, the project selection criteria could be modified so that the installation of low emissions technologies or emissions abatement equipment were tied to some proportion of funding.

Another initiative, Motorways of the Sea, is closely linked to the Marco Polo programme (Tostmann 2004). Rather than build rail systems, tunnels, and other expensive infrastructure to alleviate traffic density and environmental damage caused by road freight, EC officials advocate marine shipping, particularly for goods travelling to or from Eastern Europe. One advantage of this scheme is that Balkan and Baltic countries will be more closely tied to Western Europe by strengthening shipping links. As in the Marco Polo programme, the use of environmental guidelines in the funding process could contribute to achieving policy goals regarding air emissions from shipping.

5.4. Key Design Elements of Environmental Subsidy Programmes

This section discusses design elements for environmental subsidy programmes, both financial adjuncts to regulatory programmes and stand-alone subsidy programmes. Although many of the elements are similar, there are some additional elements for a stand-alone programme. Moreover, as noted below, many of the features of a subsidy programme are similar to those of a credit-based programme, which would allow shippers to receive emission reduction credits (“ERCs”) rather than direct financial payments.

5.4.1. Vessel Participation

The authority providing subsidies must determine which vessels should be eligible to participate and how to choose among project proposals. This section discusses the eligibility criteria; a subsequent subsection discusses the institutions and methods that might be used to choose among project subsidy proposals.

As with the credit-based approach, there are three possible lines along which the Commission might decide to restrict participation: geographic/location requirements, ship size/type, and ship owner. Each of these is discussed below.

5.4.1.1. Shipowner

A programme to provide subsidies for pollution control equipment added to new ships would have to determine which new ships would be eligible. Similarly, a programme that subsidised retrofit of existing ships with pollution control equipment would have to determine which operating vessels would be eligible.

An EU subsidiary subsidy programme is likely to be targeted to EU companies, either ship builders or ship owners; there seems little likelihood that EU governments would decide to spend funds to subsidise companies outside the EU. Note, however, that gains may “leak” outside the EU based upon the actual ownership of shipbuilding or ship operating activities. To the extent that EU shipping companies, for example, are publicly owned and traded on international stock exchanges, some of the gains provided to shippers for the installation of pollution control equipment may indirectly accrue to individuals outside the EU.

There is less ambiguity about the potential employment effects of subsidies targeted at EU shipbuilding facilities. Indeed, targeting subsidies to EU companies may be a means of keeping shipbuilding and related employment in the EU. One concern about setting EU regulations that are more stringent than international requirements is that EU companies will be economically disadvantaged if non-EU firms can avoid the regulatory requirements. Providing government subsidies for control expenditures reduces the financial disadvantages of EU companies and thus reduces the likelihood of employment losses to non-EU regions.

The usefulness of targeting EU facilities is more complicated in the case of a stand-alone subsidy programme. On the one hand, as with the financial adjunct programme, it would be desirable from an equity perspective to concentrate subsidies on EU facilities; it would be considered unfair for the EU to subsidise non-EU companies. On the other hand, allowing non-EU companies to participate in a stand-alone subsidy programme might be a means of obtaining lower cost emission reductions. As noted above in the case of credit-based programmes, the stand-alone subsidy programme would be more cost-effective if eligibility requirements did not include ownership per se. If retrofit costs are lower for non-EU ships, the cost of obtaining emission reductions could be reduced with expanded eligibility. Or, if the total amount of subsidy payments were given, the tonnes of emission reductions achieved could be increased with expanded eligibility.

5.4.1.2. Ship size/type

An adjunct subsidy programme might be limited to particular types or sizes of ships in order to reduce administrative costs of the programme. Assuming the programme had a fixed budget, it would be less expensive to administer a subsidy programme targeted on a relatively small number of large ships or shipbuilding activities. On the other hand, if one of the objectives of the subsidy programme were to provide subsidies to a large number of companies, such size limitations may be counterproductive. In the case of the adjunct subsidy programme, there is thus a potential tradeoff between reducing administrative costs and broadening the number of companies aided.

Limiting participation in a stand-alone subsidy programme to larger vessels is likely to be less important because applicants are likely to bear more of the administrative costs. Project proposals would be prepared by the companies requesting the subsidies and, indeed, the government might collect an application fee to defray some or all of the administrative costs of the programme.

5.4.1.3. Ship location

Subsidies should be restricted to ships operated in EU waters, since the emission reduction benefits otherwise would not accrue to the EU. Indeed, as with credit-based programmes, it may be desirable to provide greater restrictions (e.g., that the ship be operated only in EU waters or with a minimum time/travel spent in EU waters), although as noted above, such restrictions may inappropriately limit the potential emission reduction benefits of the programme because a substantial fraction of the shipping emissions that affect EU air quality are from large ocean-going vessels.

Note that the location of potential emission reductions can be taken into account in determining which ships/projects receive subsidies, without providing specific restrictions on the projects that can apply. As discussed below in the context of project approval, the nature of the emissions reductions expected from the project is likely to be a key determinant of which projects are approved.

5.4.2. Covered Pollutants/Measures

Subsidy programmes also must determine which pollutants and/or control measures will be targeted by the programme.

5.4.2.1. Pollutants allowed in project proposals

AQIP allows projects for a wide range of pollutants, although it focuses on the three pollutants related to mobile source controls (VOCs, NO_x, and CO). The proposals accepted for funding, however, are based upon the pollutants for which emission reductions are needed.

Programmes to provide environmental subsidies for new ship construction or ship retrofit will focus on the pollutants linked to ozone and visibility, particularly NO_x and SO₂ emissions. Stand-alone programmes thus are likely to be limited to programmes that provide for reductions in these two pollutants. Other emissions from shipping, such as PM or CO₂, would be affected, however, if controls on NO_x and SO₂ emissions led to reductions (or increases).

5.4.2.2. Measures allowed in project proposals

Subsidy programmes typically have been focused on capital costs for pollution control equipment. Thus, for example, as noted above, the Swedish subsidy programme provided financial assistance to companies installing SCR. Many other subsidy programmes emphasize the development of innovative pollution control technologies.

In theory, stand-alone subsidy programmes would not have to limit potential projects to the installation of specific capital equipment. Proposals could be accepted for scrappage programmes or even for programmes to substitute lower sulphur fuel. Nevertheless, there are reasons to restrict the range of allowable projects to those for which the agency can develop appropriate prototypes for evaluation. The AQIP programme limits potential projects to the following specific programmes:

- § Credits for the voluntary repair of on-road motor vehicles identified through remote sensing devices;
- § Old-vehicle scrapping;

- § Credits for clean on-road vehicles;
- § Mobile source credit generation pilot programme;
- § Credits for truck stop electrification;
- § Credits for clean off-road mobile equipment;
- § Credits for clean lawn and garden equipment;
- § Pilot credit generation programme for marine vessels;
- § Pilot credit generation programme for hotelling operations;
- § Pilot credit generation programme for truck/trailer refrigeration units; and
- § Pilot credit generation programme for truck stops.

A subsidy programme for shipping emissions would likely be more focused than the AQIP programme, which is designed to encourage the development of emission reduction proposals from various potential sectors. As discussed above with regard to the credit-based programme, a subsidy programme focused on shipping emissions may restrict allowable projects to specific emission reduction technologies. Broadening the range of technologies would, however, provide the opportunity for greater potential cost savings and, moreover, encourage the development of innovative emission control alternatives.

5.4.3. Other Eligibility Requirements

A subsidy programme would establish eligibility requirements, beyond determinations of what ships and measures would be allowed. The eligibility factors are similar to selection criteria, but differ in that they include threshold requirements that all potential projects must demonstrate.

The AQIP programme provides various requirements for projects in order to qualify for subsidies. To be eligible for a subsidy, a project must provide emission reductions that are “real, quantifiable, enforceable, permanent (for the duration of the emission reduction activity).”³⁵ These requirements involve the determination of a project baseline for determining emission reductions.

A subsidy programme for marine engine emission reductions would involve a similar requirement to develop a baseline as part of the eligibility requirements. As noted above with respect to credit-based programmes, setting baselines involves establishing a tradeoff between preventing “anyway tons” and making requirements so stringent that few projects would qualify.

5.4.4. Legal and Institutional Considerations

This section covers the legal concerns that would need to be accounted for prior to developing a subsidy programme. We also address one key institutional consideration.

³⁵ See www.aqmd.gov/rules/reg/reg25/r2501.pdf.

5.4.4.1. Legal considerations

The Commission has adopted the following three sets of state aid guidelines that define the context with regard to possible state subsidies for ship emissions reductions.

- § Community guidelines on state aid for environmental protection (2001/C37/03) allow aid where it serves as an incentive to firms to achieve levels of protection that are higher than those required by Community standards, or where no Community standards exist—as is the case for NO_x emissions from seagoing ships. Investment aid can be given for plant and equipment intended to reduce or eliminate pollution, but may not exceed 30 percent gross of the eligible investment costs.
- § Community guidelines on state aid to maritime transport (1997/C205/05) allow investment aid in certain circumstances to promote the use of clean ships, such as providing incentives to upgrade Community registered ships to standards which exceed mandatory environmental standards laid down in international conventions.
- § Finally, the most recent Commission framework on state aid to shipbuilding (2003/C317/O6) allows aid for research and development and allows aid up to 20 percent of gross expenditure for innovation, i.e. technologically new or substantially improved products and processes compared to the state of the art that exists in the industry.

Thus, it appears to be legally possible for Member States to provide subsidies for emissions reductions generated through the development and use of emissions abatement technologies for ships, either for new vessels or for retrofits.

5.4.4.2. Institutional considerations

One of the most significant considerations in developing a subsidy programme is determining the source of revenues used to make subsidy payments. The authority providing environmental subsidies would certainly have to address this issue before any proposed subsidy scheme was actually implemented.

Existing EU shipbuilding subsidies are generally paid for with general government revenues, as are many environmental subsidy programmes. As noted above, existing shipbuilding subsidies could in theory be differentiated on the basis of environmental criteria. Because the funds for these subsidies are already in place, this could solve the issue of where to obtain funds for a subsidy programme.

One potential alternative to providing the funds from general government revenues would be to have private firms pay into a general subsidy fund. For example, funds for the AQIP scheme come from companies that pay into the fund in lieu of having to institute more costly trip reduction and other transportation programmes. A related possibility would be to levy an environmental tax on the shipping industry for use in funding the subsidies. For example, if an environmentally differentiated port dues surcharge were introduced, these funds could then be returned to the industry in the form of an environmental subsidy.

5.5. Implementation Elements

Additional elements would be developed as an environmental subsidy programme was implemented. These are discussed in the following sections.

5.5.1. Selecting Among Eligible Project Proposals

A subsidy programme would have to determine the recipients of subsidies from among the eligible companies or project proposals. It is useful to distinguish between the procedures used by supplementary programmes from the procedures used by stand-alone subsidy programmes.

5.5.1.1. Selection of subsidy recipients in supplementary programmes

The criteria for determining recipients of subsidies designed to reduce the financial burdens of pollution control requirements would not have to relate to the cost-effectiveness of the controls. Since the subsidies would be designed to reduce financial burdens rather than to induce emission reductions, there would be no direct link between the companies receiving the subsidies and the overall cost-effectiveness of the controls. Indeed, there would be no need to quantify emission reduction gains or cost-effectiveness.

There is, however, one cost-effectiveness issue. As noted above, subsidising certain pollution control equipment may lead companies to adopt that equipment even if other means of reducing emissions (e.g., use of low-sulphur fuel) may be more cost-effective.

5.5.1.2. Selection of subsidy recipients in stand-alone programmes

The selection of recipients for a stand-alone subsidy programme is necessarily more important—at least in terms of affecting the cost-effectiveness of the controls that are put in place to reduce emissions—and more complicated than for a supplementary programme. The AQIP programme provides an example of the complexity involved in selecting projects in a stand-alone programme.

The AQIP scheme has a complex selection process that involves several steps. The first step is to divide eligible proposals (i.e., those that meet the criteria outlined above) into two categories:

- § Category I control strategy proposals are those that will achieve emission reductions within 36 months or less and for which there is a specific emissions quantification protocol available.
- § Category II control proposals are those that either: (a) provide air quality benefits within 36 months and do not have a specific emissions quantification protocol; or (b) provide air quality benefits within 36 to 60 months regardless of whether or not there is a specific emissions quantification protocol.

Under the AQIP scheme, Category I proposals are selected until the total number of required emission reductions is achieved. Thus, Category II proposals are only accepted if insufficient Category I projects are available.

The AQIP regulations call for Category I projects to be prioritised based upon the following criteria:

- § Incremental cost of the programme;
- § Amount of emission reductions (for each individual pollutant);
- § Ability to achieve concurrent or multiple pollutant emission reductions;

- § Viability of partial or full implementation of the proposal and associated implementation cost for partial and/or full implementation of the proposal;
- § Type of control strategy;
- § Location of control strategy;
- § Monitoring, recordkeeping, and reporting elements of the proposal;
- § Consistency with other local, state and federal programmes;
- § Potential adverse environmental impacts;
- § Implementation period of the control strategy; and
- § Achieving a balance between different types of strategies.

With regard to costs and cost-effectiveness, the requirements of the requests for proposals calls for proposals to specify the amount of funding requested—including a cost breakdown of expenditures—and to indicate clearly the cost-effectiveness of the project, in dollars per total pound of pollutants to be reduced according to the following formula:

$$\text{§ Total annual emission reduction (lbs)} = \text{VOC} + \text{NO}_x + (\text{CO}/7)$$

$$\text{§ Cost-effectiveness} = (\text{Funding request} * \text{capital recovery factor}) / (\text{total annual emission reduction})$$

The capital recovery factor is based upon a discount rate of three percent.

The various projects are then divided into seven categories based upon the nature of the project (e.g., marine vessel repowering, old-vehicle scrapping). The on-road projects are given priorities in the selection process (because the emission reductions are designed to substitute for on road reductions), with projects evaluated specifically by each evaluator based upon several criteria, of which cost-effectiveness is weighted 35 percent. (Additional points are given if the project is proposed by a small business or a minority- or woman-owned business, as called for in general procurement guidelines). In sum, the AQIP selection process is complex, including the incorporation of various general procurement provisions.

Setting procurement guidelines for a stand-alone environmental subsidy programme for the EU maritime sector would need to include many of the same guidelines relevant for assessing credit-based programmes, including determining the baseline and estimating the level of emissions reductions that could be achieved. However, these could be done in a relatively simplistic manner and would certainly not require the technical rigour discussed for either the credit-based or the benchmarking approaches.

The issue of geography would also need to be addressed, since the primary objective of the programme would be to effect environmental improvements in the EU. As such, the subsidy scheme would almost certainly need to focus on projects that directed most of their emissions benefits in the EU region. This would need to be accounted for in the project selection process.

5.5.2. Monitoring and Reporting

Subsidies that supplement other regulatory programmes would need to monitor that recipients complied with whatever requirements were established as conditions for the programme, which generally would not involve monitoring of emissions. Indeed, if the programme focused on the installation of a few specific technologies, once installation was completed, there would probably be little need to monitor. Of course, a subsidisation of SCR represents a potential exception since there are significant costs associated with its continued operation. As a result, shipowners would have some incentive not to operate the technology even after it was installed. Thus, some sort of periodic monitoring might be required to ensure that shipowners were actually operating subsidised technology. However, this monitoring would probably be accomplished in the context of the accompanying regulatory programme (e.g., the port dues scheme as in the Swedish case).

Alternatively, if the subsidy scheme were linked to a separate environmental classification (e.g., the Green Award) or environmental index (as discussed in the previous chapter), the programme could rely on the certifying body to manage any monitoring and reporting requirements.

If the subsidy scheme were intended to stand on its own, some monitoring might be required in order to estimate the level of emissions reductions being achieved from the programme. As noted, these types of estimates are required in the AQIP programme. Realistically, however, it would probably involve, a subsidy scheme would probably involve at most periodic monitoring. A high level of accuracy would likely not be critical for a subsidy scheme and thus major expenditures on monitoring would probably not be warranted.

5.5.3. Programme Administration

Like many of the other schemes discussed here, the level of resources needed to administer the programme would depend on the level of complexity. One advantage of a subsidy approach is that it would probably not be particularly rigorous and thus would not involve a substantial investment of time from the administrator. (Of course, the level of resources necessary to *fund* the programme, including the subsidies, could be substantial.) While there would be some time spent reviewing project proposals, there would probably be little need for monitoring or significant expenditures once projects were underway. As a result, the overall administrative costs of a subsidy scheme would probably be low.

6. Emissions Impacts and Costs

This chapter provides preliminary quantitative information on the potential environmental and cost-effectiveness effects of two of the economic instruments considered in this report, the credit-based approach and the consortium benchmarking approach. We use data developed by Entec (2005a-e) to characterise the vessels that might participate in these approaches and the costs of the various SO₂ and NO_x control technologies that might be employed. Developing estimates of the likely effects of these two approaches requires many assumptions; we emphasise that these results are illustrative rather than precise. Nevertheless, the empirical information provides insights on how specific programmes might be designed and what their environmental and economic effects might be.

The chapter is organised as follows. The first section describes basic data on the vessels assumed in the analyses, including their operating and emissions characteristics. The following section uses the Entec cost information and the vessel operation characteristics to develop information on emission reduction costs; the third section develops illustrative cost curves for the abatement of emissions of SO₂ and NO_x under various assumptions regarding the geographic region that would be covered by the credit or benchmarking programmes. The fourth section summarises the nature of the credit and benchmarking approaches, and also provides a characterisation of the baseline regulations assumed for these approaches. The final section presents the illustrative results regarding emissions, costs and potential cost savings.

6.1. Vessel Activity Data and Assumptions

The data used in this analysis were taken from recent reports by Entec (2005a-e). These describe the composition of vessels in EU waters, their operating and emissions characteristics, and the costs and effectiveness of different technologies to reduce NO_x and SO₂ emissions. Most of the information in the reports relate to three vessel sizes (small, medium and large). Table 8 shows the general characteristics of the engines assumed on vessels of each type used in our analysis.

Table 8. Operating Characteristics and Assumptions by Vessel Size

	Small	Medium	Large
Main Engine Size (kW)	3,000	10,000	25,000
Auxiliary Engine Size (kW)	500	1,500	4,000
Proportion of Total Ships Worldwide (%)	60%	30%	10%

Source: Entec 2005a.

Note: Entec 2005a assumes that each vessel has one main engine and four auxiliary engines. The figure shown for auxiliary engines in this table is total capacity of all four engines.

As in the study by Entec, we assume that for each vessel type there are three ages: new,, which were built in the last year; young, built in the last fifteen years; and old, built before 1990. Entec assumes an annual renewal rate of approximately 4 percent and therefore new vessels are four percent of the total population, young vessels are 56 percent of the population and old vessels comprise the remaining forty percent.³⁶ For the purposes of this analysis,

³⁶ The 4 percent figure is extrapolated from Table 6.1 of Appendix b of Entec 2005, which shows that the “renewal rate” for EU-flagged vessels is about 4 percent. Note that this does not account for sector growth in the overall fleet, and also

NERA assumed that the total number of vessels weighing in excess of 500 gross tonnes worldwide is 31,000.³⁷ Table 9 shows how these assumptions translate into the total number of vessels in each size and age category when the Entec distribution is applied.

Table 9. Assumed Vessel Population by Size and Age

	New	Young	Old
Small	660	7,920	8,250
Medium	420	5,040	5,250
Large	120	1,440	1,500

Source: Entec 2005a and NERA calculations.

The Entec study also estimates the amount of energy used by each vessel size category while at sea, at berth and manoeuvring. Table 10 shows the amount of energy used by a single vessel of each ship size in each operating activity for both the main engine and the four auxiliary engines.

Table 10. Assumed Per Vessel Activity by Size and Engine (MWh/year)

	Small	Medium	Large
<i>Main Engine</i>			
At Sea	14,400	48,000	120,000
At Berth	21	70	175
Manoeuvring	12	40	100
Total Main Engine	14,433	48,110	120,275
<i>Auxiliary Engines</i>			
At Sea	1,008	2,664	6,840
At Berth	157	414	1,064
Manoeuvring	6	15	38
Total Aux. Engines	1,170	3,093	7,942
Total Usage	15,603	51,203	128,217

Source: Entec 2005a

Note: These usage figures are assumed to be a snapshot of a given year of activity

Entec uses these energy-use assumptions to estimate yearly emissions for each vessel size and location. For the purposes of the cost-effectiveness calculations in the SO₂ and NO_x abatement reports, Entec assumed emissions rates of 15 g/kWh for NO_x and 11 g/kWh for SO₂.³⁸ Table 11 shows the assumed emission per vessel of NO_x for each vessel type, engine type, and geographic zone.

assumes that the renewal of vessels occurs evenly across the vessel categories (i.e. it overlooks the possibility that a large vessel may be built to replace a medium-sized one that is retired).

³⁷ Worldwide vessel population supplied by Entec.

³⁸ The IMO NO_x Curve described in Marpol Annex VI indicates that NO_x emissions rates are typically a function of engine speed. However, in order to simplify the calculations in the cost-effectiveness analysis, Entec assumes a single average emissions rate. Furthermore, Entec notes that most newer ships will include basic internal engine modifications ("bIEM") by the time any regulation goes into effect. Therefore, the future business as usual ("BAU") fleet average NO_x emissions rate reflects a slight drop in NO_x emissions from the current average..

Table 11. Estimated Annual NO_x Emissions per Vessel (tonnes/year)

	Small	Medium	Large
<i>Main Engine</i>			
At Sea	216	720	1,800
At Berth	0.3	1.1	2.6
Manoeuvring	0.2	0.6	1.5
Total Main Engine	216	722	1,805
<i>Auxiliary Engines</i>			
At Sea	15	40	103
At Berth	2.4	6.2	16.0
Manoeuvring	0.1	0.2	0.6
Total Aux. Engines	18	46	119
Total NO_x Emissions	234	768	1,924

Source: Entec 2005a

Table 12 shows the estimated yearly SO₂ emissions by size, location and engine.

Table 12. Estimated Annual SO₂ Emissions per Vessel (tonnes/year)

	Small	Medium	Large
<i>Main Engine</i>			
At Sea	158	528	1,320
At Berth	0.2	0.8	1.9
Manoeuvring	0.1	0.4	1.1
Total Main Engine	159	530	1,323
<i>Auxiliary Engines</i>			
At Sea	11	29	75
At Berth	1.7	4.6	11.7
Manoeuvring	0.1	0.2	0.4
Total Aux. Engines	13	34	87
Total SO₂ Emissions	172	564	1,411

Source: Entec 2005a

As the tables suggest, the vast proportion of emissions occur while at sea. However, the activity that produces the energy use and emissions presented above may not necessarily be spent entirely in EU waters or in waters that will have emissions regulations. Furthermore, there is likely to be a distribution of times spent in EU waters for each vessel size category. Therefore, in its simulations NERA considered different distributions of time spent in three geographic regions that may be relevant: waters within 200 and 12 miles from EU coasts, and waters within a SECA (currently the English Channel, North Sea and Baltic Sea). Table 13 shows the assumed distribution of the percent of time each ship size spends in each geographic zone.

The data presented in Table 13 are approximate and should be treated cautiously, but they are helpful in providing a first approximation of information that is necessary to understand abatement incentives, as discussed below. The distributions for all EU sea areas and for SECA waters are estimated based on the proportions of calls at ports within the respective sea area. (Estimates for the 12-mile zone are based on the ratio of 12-mile activity to 200-mile activity.)

The table should be read as follows: the top row of the table corresponds to the activity of vessels that spend the most time in European waters, whereas the bottom row corresponds to vessels with the least activity in Europe. The table indicates, for example, that among small vessels, one quarter are assumed to spend on average 65 percent of their time in the EU 200-mile Exclusive Economic Zone, another quarter spend on average 25 percent of their time in this region, and the remaining half of small vessels (the third and fourth quartiles) spend no time at all these waters.³⁹

Table 13. Distribution of Time Spent In EU Waters, by Vessel Size and Quartile

	<i>In Exclusive Economic Zone</i>			<i>In 12-Mile Zone</i>			<i>In SECA Waters</i>		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
First Quartile	65%	50%	50%	13%	10%	10%	30%	20%	20%
Second Quartile	25%	20%	20%	5%	4%	4%	5%	5%	5%
Third Quartile	0%	0%	5%	0%	0%	1%	0%	0%	0%
Fourth Quartile	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Data provided by Entec

6.2. Emissions Abatement Effectiveness and Costs

Entec reviewed the costs and emissions reduction potential of a number of different control technologies for SO₂ and NO_x. This section summarises their findings for use in our analysis.

6.2.1. NO_x Abatement Measures

Entec considered several measures for NO_x abatement, including:

- § Basic and Advance Internal Engine Modifications (“IEM”);
- § Direct Water Injection (“DWI”);
- § Humid Air Motors (“HAM”);
- § Exhaust Gas Recirculation (“EGR) and,
- § Selective Catalytic Reduction (“SCR”).

Entec does not provide full cost estimates for EGR, due to the lack of experience of its commercial application to ships and the associated high uncertainty of cost estimates, and it is therefore not considered as a reduction option in our analysis. Table 14 shows the percentage reduction in NO_x emissions that result from installation of each of the remaining five measures for main and auxiliary engines.

³⁹ Data on port calls were used to create a distribution of vessel activity by type. We scaled this distribution so that when combined with Entec’s estimates of average vessel characteristics and activity, the resulting emissions in EU and SECA waters are in line with Entec’s respective emissions estimates. Activity distribution has been rounded up to the nearest five percent for 200-mile and SECA activity.

Table 14. Percent NO_x Reductions from Various Abatement Options by Engine

	Main Engine	Auxiliary Engine
Basic IEM	20%	N/A
Advanced IEM	30%	30%
DWI	50%	50%
HAM	70%	70%
SCR	90%	90%

Source: Entec 2005a

Entec estimates the costs of installing each technology on the different sized vessels. For Basic IEM these costs were distinguished between “young” and “old” engines. For HAM and SCR, costs are differentiated between retrofits and new builds. Table 15 shows the capital cost of each technology by vessel size and vessel age, and Table 16 shows the variable cost of operating each technology.⁴⁰

Table 15. Capital Costs of NO_x Abatement Technologies per Vessel (€/ Year)

	Small		Medium		Large	
	New	Young and Old	New	Young and Old	New	Young and Old
Basic IEM	497	2,595	1,336	3,435	3,135	5,234
Advanced IEM	6,867	N/A	7,666	N/A	11,047	N/A
DWI	14,944	14,944	29,791	29,791	60,438	60,438
HAM	41,625	47,769	116,240	143,720	246,798	334,837
SCR	20,322	34,983	47,256	81,347	108,595	186,937

Source: Entec 2005c

Note: For young vessels, the cost of basic IEM is the same as that for new vessels. Furthermore, Entec indicates that all young and new vessels that are able to install basic IEM (these represent 36 percent of the overall fleet) will already have done so as a matter of course. Only a small fraction (3 percent) of old vessels that could install basic IEM would do so under Business as Usual, however..

Table 16. Operating Cost of NO_x Abatement Technologies (€/ Year)

	Small	Medium	Large
Basic IEM	0	0	0
Advanced IEM	0	0	0
DWI	33,190	108,560	271,000
HAM	2,360	7,660	19,120
SCR	135,520	342,061	801,200

Source: Entec 2005c

Note: SCR costs are based on Entec’s assumptions for vessels using residual oil. For further discussion please see footnote 40.

⁴⁰ Note that the distinction between “young” and “old” vessels is only pertinent for basic IEM. Also, Entec 2005 shows two costs for SCR, depending on whether a vessel uses marine distillate oil or residual oil. Use of residual oil results in faster decay of the SCR unit and therefore an accelerated replacement schedule. We present results assuming that residual oil is used, which is the more expensive scenario. The cost difference varies according to vessel activity. For instance, for an existing large vessel in the top EU activity quartile that retrofits SCR for use in all EU sea areas, the full cost of SCR will be 30 percent lower if the vessel uses distillate. The full cost of SCR will be only 20 percent lower if the same vessel is in the second activity quartile. Beyond the second quartile, there is a negligible difference in the cost of running SCR, since it would rarely be used.

Table 17 shows the total cost of installing and operating each of the NO_x technologies considered in this study, using the operating levels shown in Table 10.

Table 17. Total Cost of NO_x Abatement Technologies (€/ Year)

	Small		Medium		Large	
	New	Young and Old	New	Young and Old	New	Young and Old
Basic IEM	497	2,595	1,336	3,435	3,135	5,234
Advanced IEM	6,867	N/A	7,666	N/A	11,047	N/A
DWI	48,134	48,134	138,351	138,351	331,438	331,438
HAM	43,985	50,129	123,900	151,380	265,918	353,957
SCR	155,842	170,503	389,317	423,408	909,795	988,137

Source: Entec 2005c

6.2.2. SO₂ Abatement Technologies

Entec considered the following three methods for reducing SO₂ emissions:

- § Switch from fuel with 2.7 percent sulphur content to fuel with 1.5 percent sulphur,
- § Switch from fuel with 2.7 percent sulphur to fuel with 0.5 percent sulphur, and
- § Install a sea water scrubber (“scrubber”).

In its scenario analysis and marginal abatement cost curve derivations, NERA also considered the costs of vessels switching from 2.7 percent to 0.1 percent fuel while in port.

Table 18 shows the percentage reduction in SO₂ emissions that results from these options.

Table 18. Percent SO₂ Reduction from Various Abatement Options

Abatement Option	Emissions Reduction
1.5% Sulphur Fuel	44%
0.5% Sulphur Fuel	81%
0.1% Sulphur Fuel	96%
Scrubber	75%

Source: Entec 2005d

Note: 0.1 percent sulphur fuel is considered relevant only for emissions at berth.

The cost of implementing each of these measures varies by vessel size and (for sea water scrubbers) whether the vessel is a new build or requires a retrofit. The capital costs of implementing these technologies are shown in Table 22, and the operating costs are shown in Table 25.⁴¹

⁴¹ In estimating the cost of different SO₂ abatement measures, Entec assumes that vessels switch entirely from high sulphur fuel oil to low sulphur fuel, to simplify the cost-effectiveness calculations. Vessels therefore do not need to install additional fuel tanks or modify existing tanks to accommodate multiple fuels, so the fuel switching measures involve no capital costs. Moreover, because vessels are assumed to use only one type of fuel, the variable cost estimates do not reflect the costs of switching between different fuels, which may require draining all fuel from the engine, heating of the new fuel, and re-flooding of the engine with the new fuel, all of which are likely to impose additional costs on the

Table 19. Capital Cost of SO₂ Abatement Options by Vessel Size (€/ Year)

	Small		Medium		Large	
	Young and		Young		Young	
	New	Old	New	and Old	New	and Old
1.5% Sulphur Fuel	0	0	0	0	0	0
0.5% Sulphur Fuel	0	0	0	0	0	0
0.1% Sulphur Fuel	0	0	0	0	0	0
Scrubber	37,700	61,750	121,460	199,090	304,630	499,440

Source: Entec 2005d and NERA calculations based on Entec 2005d.

Table 20. Operating Cost of SO₂ Abatement Options by Vessel Size (€/Year)

	Small		Medium		Large	
	Young and		Young		Young	
	New	Old	New	and Old	New	and Old
1.5% Sulphur Fuel	93,620	93,620	307,219	307,219	769,302	769,302
0.5% Sulphur Fuel	234,051	234,051	768,048	768,048	1,923,255	1,923,255
0.1% Sulphur Fuel	441,458	441,458	1,448,662	1,448,662	3,627,568	3,627,568
Scrubber	12,560	12,560	27,001	27,001	33,869	33,869

Source: Entec 2005d and NERA calculations based on Entec 2005d. Where applicable, fuel switching costs are from CONCAWE estimates.

Table 21 combines the fixed and variable costs for SO₂ technologies shown above and displays the total cost of installing each technology, using the operating characteristics described in Table 10.

Table 21. Total Cost of SO₂ Abatement Options by Vessel Size (€/Year)

	Small		Medium		Large	
	Young and		Young		Young	
	New	Old	New	and Old	New	and Old
1.5% Sulphur Fuel	93,620	93,620	307,219	307,219	769,302	769,302
0.5% Sulphur Fuel	234,051	234,051	768,048	768,048	1,923,255	1,923,255
0.1% Sulphur Fuel	441,458	441,458	1,448,662	1,448,662	3,627,568	3,627,568
Scrubber	50,260	74,310	148,461	226,091	338,499	533,309

Source: Entec 2005d and NERA calculations based on Entec 2005d. Where applicable fuel switching costs are from CONCAWE estimates.

6.2.3. Shore-side Electricity (“Shore Power”)

As a final means of reducing emissions, Entec considers the costs for vessels at berth to use shore-side electricity (hereafter “shore power”, but also known as “cold-ironing”). For each vessel, this would have the effect of eliminating the at-berth emissions shown in Table 11 and Table 12. However, because land-based electricity generators may also be sources of

operator. The per-tonne abatement costs associated with the use of different fuels is therefore likely to be underestimated for some vessels, although quantification of this would require detailed analysis outside the scope of this study. (The primary focus of Entec’s work on SO₂ abatement has been on sea water scrubbing.)

emissions, the net effect on emissions of using shore power will depend on the characteristics of the electricity sector supplying electricity to vessels. This is discussed in more detail in Entec's separate report on shore power. Table 22 shows the capital cost to each vessel of using shore power, while Table 23 shows the annual operating cost incurred by each vessel, taking account of time spent in port. Note that the tables only reflect the costs of shore power that would be incurred *directly* by vessel operators, but they do *not* include infrastructure costs incurred by ports.⁴²

Table 22. Capital Cost of Using Shore Power by Vessel Size (€/Year)

	New Build	Retrofit
Small	9,798	14,150
Medium	14,289	20,566
Large	25,313	36,314

Source: Entec 2005b

Table 23. Operating Cost of Using Shore Power by Vessel Size (€/Year)

	Operating Cost
Small	1,445
Medium	5,997
Large	17,216

Source: Entec 2005b

Note: The costs shown in the table above are incremental to the operating costs incurred from the vessel switching to 0.1% sulphur fuel

Table 24 shows the total cost of using shore power.

Table 24. Total Cost of Using Shore Power by Vessel Size (€/Year)

	New Build	Retrofit
Small	11,243	15,595
Medium	20,287	26,563
Large	42,529	53,530

Source: Entec 2005 b

Note: The costs shown in the table above are incremental to the operating costs incurred from the vessel switching to 0.1% sulphur fuel

Table 25 shows the net reduction in NO_x and SO₂ that results from using shore power, compared both to 2.7 percent sulphur fuel and 0.1 percent sulphur fuel.

⁴² Entec 2005 also estimates the costs that would be borne by the *port* to install the facilities necessary to allow use of shore power. For the purposes of this analysis, we have assumed these costs will either be carried by the port or will be supported by subsidies, and that these costs will *not* therefore be passed through to vessels. If ports' costs were passed on to vessel operators, the total costs to vessels could be substantially greater.

Table 25. Net Emissions Reduction from Use of Shore Power (g/kWh)

	Net Reduction (g/kWh)	
	Relative to 2.7%	Relative to 0.1%
NO _x	12.1	11.4
SO ₂	11.8	0.0

Source: Entec 2005c

Note: Entec 2005b describes the alternative baseline sulphur emissions factors used in for the various Entec tasks (Entec 2005b-e). Because of the baseline assumed to apply in the case of shore power, the emissions reduction shown relative to 2.7 percent is greater than the average factor used in the rest of this report which includes some use of marine diesel

6.3. Marginal Abatement Costs

Using the assumptions presented above, we have calculated the marginal cost of each abatement measure per tonne of pollutant abated. We use this information at the end of the section to construct Marginal Abatement Cost Curves (“MACCs”) for each pollutant. The MACCs show the additional cost of reducing incremental tonnes of pollutant, over and above the cost of the previous (less costly) reductions.⁴³

We construct different marginal costs based upon different assumptions about the shipping emission reductions that are considered relevant under a given policy. For example, policies could focus on emissions in ports or within 12 miles from shore, on the presumption that these nearby emissions are primarily responsible for the environmental effects of shipping emissions. Alternatively, some policies may focus on emissions within SECAs. As noted above, evidence regarding the relative environmental significance of emissions at different distances from shore is currently limited. If emphasis is put on reducing emissions closer to shore, the total “relevant” emissions reductions from the various technologies will be significantly smaller, but for some of the technologies the total costs will not be affected. Based on information in Entec (2005a), NERA assumes that about 20 percent of all ship emissions occur within 12-miles of the coastline.

Given these considerations, we develop estimates of the cost per tonne of emissions reduced at berth, within 12 miles of shore, and across all EU sea areas. We also consider the costs of reducing SO₂ emissions in SECAs. In cases where the geographic area of interest is smaller, the costs per tonne of abatement rise significantly because fewer “geographically relevant” emissions are reduced for a given control technology. These calculations effectively assume that emissions reductions outside the respective geographic zone are of *no* environmental benefit, and therefore are not relevant to any cost-effectiveness calculations. This assumption presumably understates the actual benefits of such reductions. Thus the higher costs per tonne can be thought of as a ceiling on the costs per tonne abated, since many of the abatement measures will also reduce emissions outside the geographic zone being presented in the tables.

Table 26 shows the cost per tonne of NO_x reduced for each measure described above, when the reductions are applied to all vessel emissions occurring in the different geographic regions. Also note that costs for the use of shore-side electricity are only shown for in-port emissions.

⁴³ The cost estimates do not include the costs of monitoring emissions.

Table 26. Cost of NO_x Technologies per Tonne Reduced by Ship Size and Age, by Geography (€/Tonne)

	Small		Medium		Large	
	New	Young and Old	New	Young and Old	New	Young and Old
<i>All Emissions</i>						
Basic IEM	12	60	9	24	9	15
Advanced IEM	98	N/A	33	N/A	19	N/A
HAM	268	306	230	282	198	263
DWI	411	N/A	360	N/A	345	N/A
SCR	740	809	563	612	526	571
Shore Power	-	-	-	-	-	-
<i>12-Mile Emissions</i>						
Basic IEM	60	300	46	125	48	77
Advanced IEM	489	N/A	166	N/A	96	N/A
HAM	1,285	1,472	1,095	1,351	930	1,257
DWI	920	N/A	669	N/A	595	N/A
SCR	1,125	1,467	838	1,086	777	1,003
Shore Power	-	-	-	-	-	-
<i>In Port Emissions</i>						
Basic IEM	8,220	41,100	6,362	14,929	5,725	8,723
Advanced IEM	8,583	N/A	3,517	N/A	1,942	N/A
HAM	22,311	25,602	22,868	28,271	18,609	25,243
DWI	11,488	N/A	8,481	N/A	6,651	N/A
SCR	9,149	15,211	7,723	12,938	6,846	11,451
Shore Power	9,662	12,086	5,371	6,631	3,847	4,704

Source: NERA calculations.

Note: The cost of basic IEM for young vessels is the same as that for new vessels. Also note that basic IEM becomes less cost-effective at berth because it is less effective on auxiliary engine emissions.

Table 27 shows similar costs for SO₂ technologies for the same geographical areas. Note that the measures involving low-sulphur fuel have the same cost per tonne for all vessel types because we assume that vessels are able to use the low sulphur fuels only when necessary without incurring any additional capital costs or fuel-switching costs (see footnote 41), and fuel costs alone would not vary across vessels. Again, the costs of measures where the relevant emissions reductions occur only while in port (including the use of 0.1 percent MDO and shore power) are only shown in the last section of the table.

Table 27. Cost of SO₂ Technologies per Tonne Reduced by Ship Size and Age, by Geography (€/Tonne)

	Small		Medium		Large	
	New	Young and Old	New	Young and Old	New	Young and Old
<i>All Emissions</i>						
1.5% Sulphur	1,230	1,230	1,230	1,230	1,230	1,230
0.5% Sulphur	1,690	1,690	1,690	1,690	1,690	1,690
0.1% Sulphur	-	-	-	-	-	-
Scrubber	390	579	351	535	320	504
Shore Power	-	-	-	-	-	-
<i>12-Mile Emissions</i>						
1.5% Sulphur	1,230	1,230	1,230	1,230	1,230	1,230
0.5% Sulphur	1,690	1,690	1,690	1,690	1,690	1,690
0.1% Sulphur	-	-	-	-	-	-
Scrubber	1,850	2,600	1,600	2,500	1,430	2,360
Shore Power	-	-	-	-	-	-
<i>In Port Emissions</i>						
1.5% Sulphur	1,230	1,230	1,230	1,230	1,230	1,230
0.5% Sulphur	1,690	1,690	1,690	1,690	1,690	1,690
0.1% Sulphur	2,326	2,326	2,326	2,326	2,326	2,326
Scrubber	30,060	46,200	36,040	56,800	29,460	45,070
Shore Power	9,889	12,370	5,498	6,788	3,937	4,815

Source: NERA calculations.

Note: 0.1 percent Sulphur fuel is also referred to as Marine Distillate Oil (“MDO”)

6.3.1. Illustrative Marginal Abatement Cost Curves

Using the information above, NERA was able to construct illustrative marginal abatement cost curves (“MACCs”) for a variety of scenarios for NO_x. Each MACC indicates what it would cost for additional tonnes of emissions abatement, given a certain level of overall shipping activity. The curves should be considered illustrative because of uncertainties associated with a number of the assumptions used to calculate them.

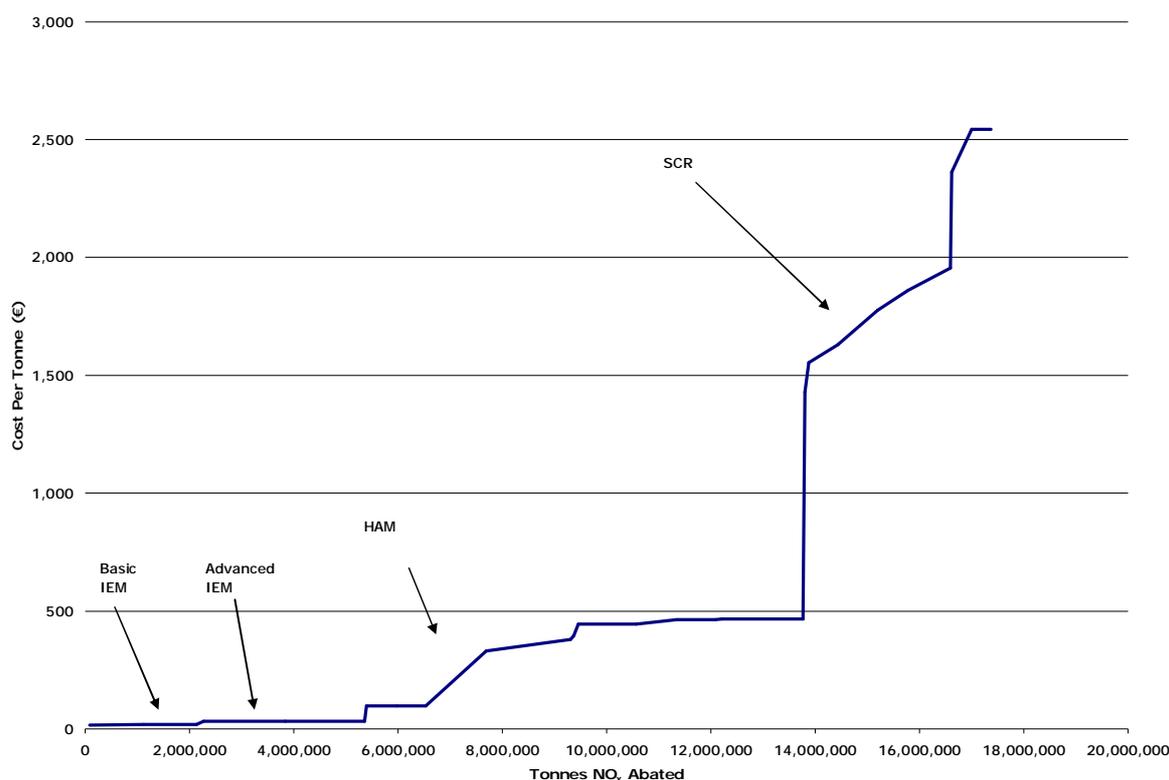
A MACC is a depiction of the additional cost of incremental or *marginal* emission reductions that each technology provides, and therefore the costs shown in these figures cannot be matched one-for-one with the average costs shown in Table 26 and Table 27 above. The figures below show the additional amount that must be paid to gain additional reductions from more effective technology. For example, the *marginal* cost per tonne of choosing SCR over HAM will be significantly greater than the marginal cost of moving from no control to SCR because the incremental emissions reduction associated with making a choice to install SCR instead of HAM is much less than the *total* reduction associated with SCR.

6.3.2. Illustrative MACCs for NO_x Emission Reductions

Figure 2 shows a basic MACC for NO_x, which includes all shipping emissions and does not attempt to apply any assumptions about distribution of activity. That is, this curve assumes that all vessels spend 100 percent of their time in the relevant waters. Note that DWI is not shown in the figure—because its full cost, when all activity is considered relevant, is greater

than HAM, but its effect on emissions is lower. This suggests that HAM would always be installed over DWI if there were no geographical considerations.⁴⁴ As noted above, all eligible young and new vessels will install basic IEM as a matter of course, along with 3 percent of older vessels. Since these vessels will install the technology regardless of whether emissions limits exist, the reductions and costs per tonne shown in the following figures do not incorporate this option, and the portion of the curve that is identified as basic IEM corresponds only to the technology’s installation on the remaining older vessels that do not install the technology under “business as usual” (“BAU”).

Figure 2. MACC for NO_x, No Geographical Considerations



Source: NERA calculations.

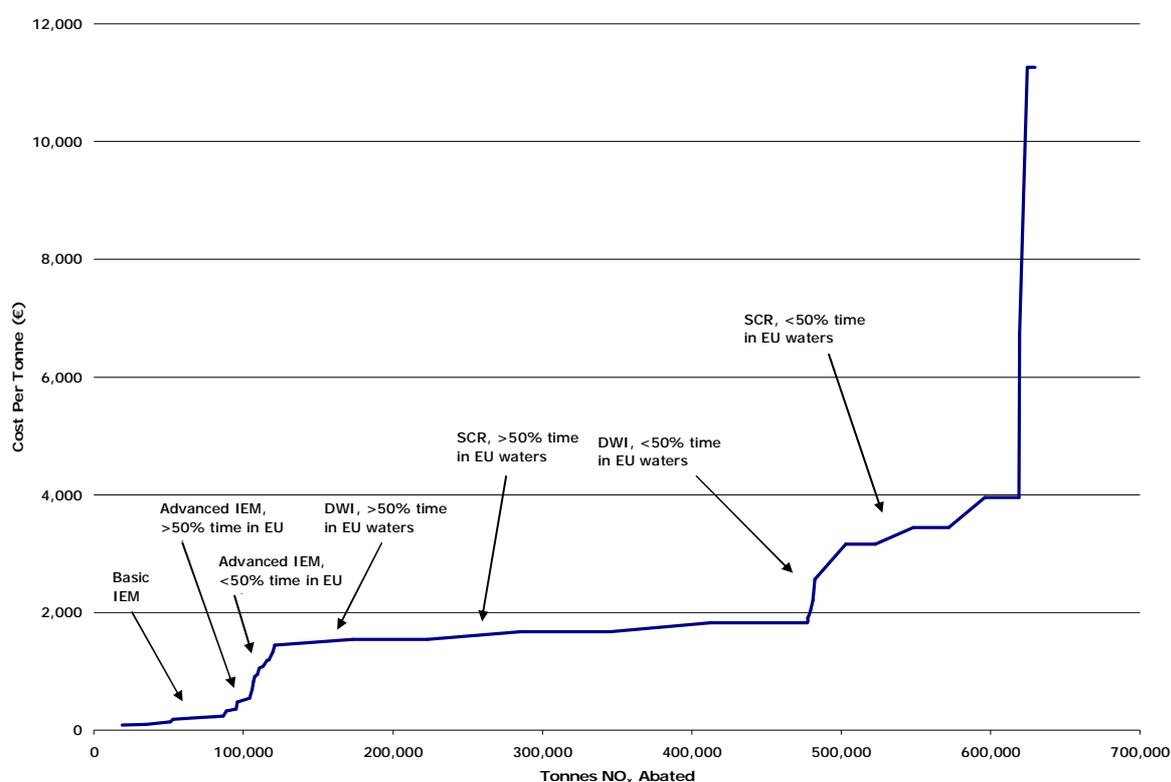
As noted above, Figure 2 is based on the assumption that all vessels in any one year spend all of their time in the relevant waters. This is clearly unrealistic and is important to correct, because the time spent in EU waters (or other waters with emissions restrictions) has important implications for the incentives to undertake emissions abatement. To correct this assumption, we develop additional MACCs based on the distribution of time spent in relevant waters presented in Table 13.

The following three figures show the marginal costs of reducing tonnes of NO_x emissions in each of the three emissions zones considered (all EU sea emissions, 12-mile emissions, and emissions at berth), accounting for the amount of time ships actually spend in these waters. As the figures indicate, the variation in the amount of time a vessel spends in relevant waters

⁴⁴ The cost estimates provided by Entec for HAM and DWI are preliminary, however, because these technologies are currently in relatively limited use. It is therefore possible that for certain vessels DWI could be more attractive.

has a significant impact on the marginal costs of emissions reductions. The costs per tonne of emissions reduced increase as the geographical area of interest becomes smaller, because fewer tonnes of emissions are considered “relevant” for the evaluation. The higher costs are reflected in the scale of the vertical axes of the figures, and the smaller level of emissions is reflected in the horizontal axes. There are still significant opportunities for emissions abatement when geography is taken into account, but now the particular technology chosen will depend upon the amount of time a vessel spends in the relevant waters. Figure 3 shows the MACC using the activity distributions shown in Table 13 for emissions within 200 miles of EU coasts. As for Figure 2, DWI does not appear on this curve, because HAM is less expensive when operating and capital costs are taken into consideration, and offers greater emissions reductions.⁴⁵

Figure 3. MACC for NO_x, EU 200-Mile Zone

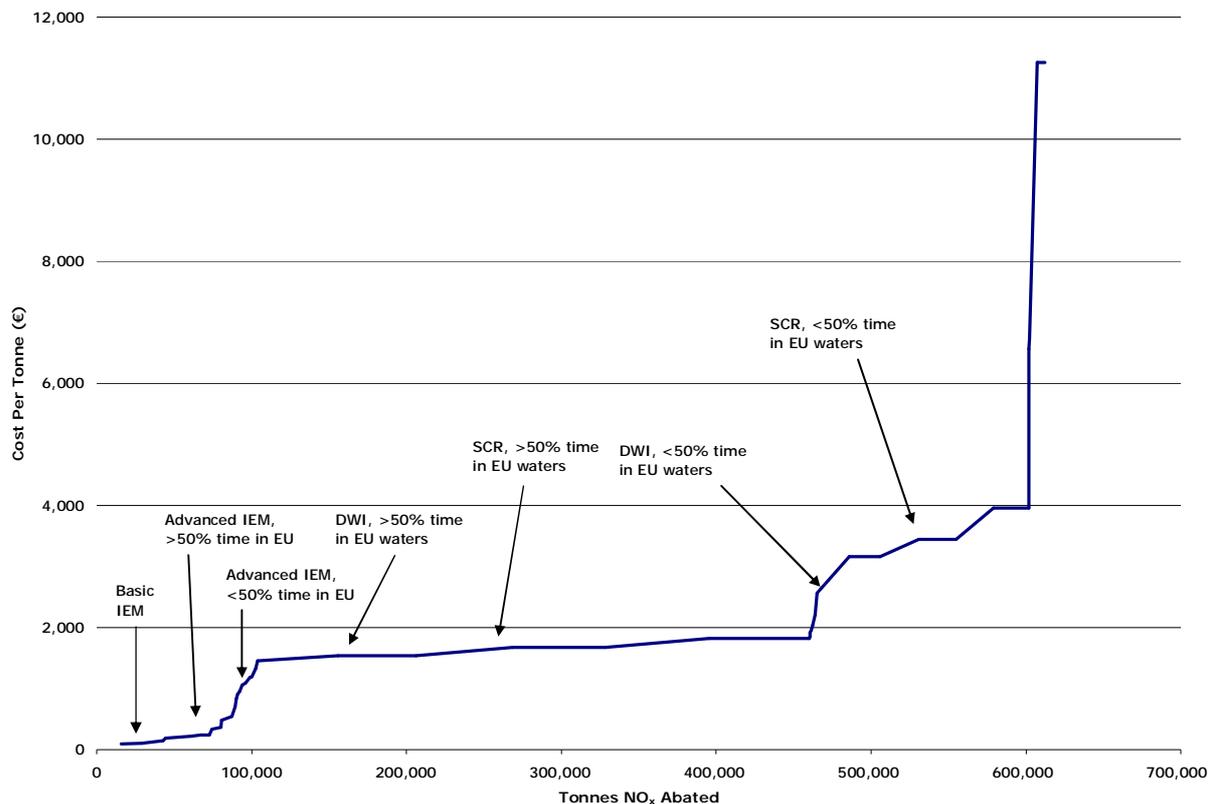


Source: NERA calculations

Figure 4 shows the MACC for NO_x emissions reductions when only 12-mile emissions are considered relevant. In this curve, HAM does not appear, but DWI does. This is because DWI has lower capital costs than HAM: because a smaller proportion of total activity is considered relevant, the much higher operating costs of DWI do not weigh as heavily against the technology as when a higher proportion of activity is “covered” by the policy requirement.

⁴⁵ Note that for certain combinations of vessel types and activity patterns, vessels using distillate rather than residual oil could find SCR more attractive than some of the other technologies.

Figure 4. MACC for NO_x, EU 12-Mile Zone

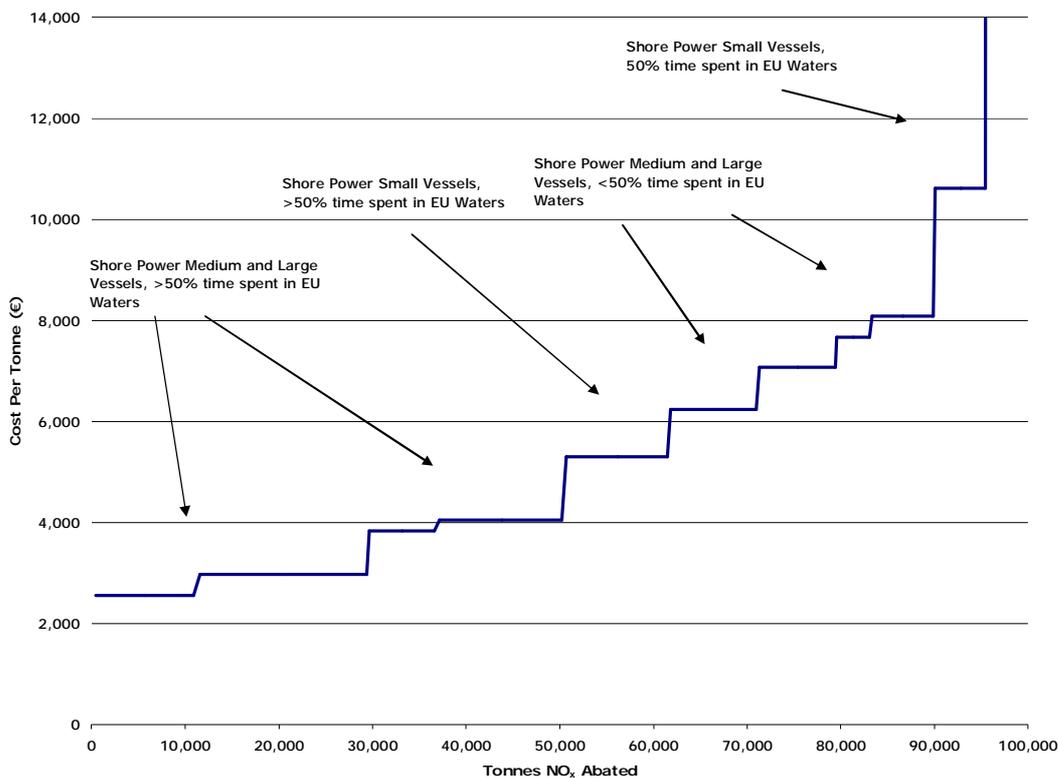


Source: NERA calculations.

Figure 5 shows the MACC associated with reducing at berth emissions only. Shore power is the only option that appears in the figure, because the costs of abating only at berth emissions using any of the other technologies becomes prohibitively high. Thus if emissions in port are the only emissions of concern to policy-makers, shore power appears to be an important option.⁴⁶

⁴⁶ Again, recall that the abatement costs shown for shore power include only the costs incurred *directly* by vessels. They do not reflect the significant additional costs to ports of providing the infrastructure to allow shore power.

Figure 5. MACC for NO_x, At Berth Emissions Only

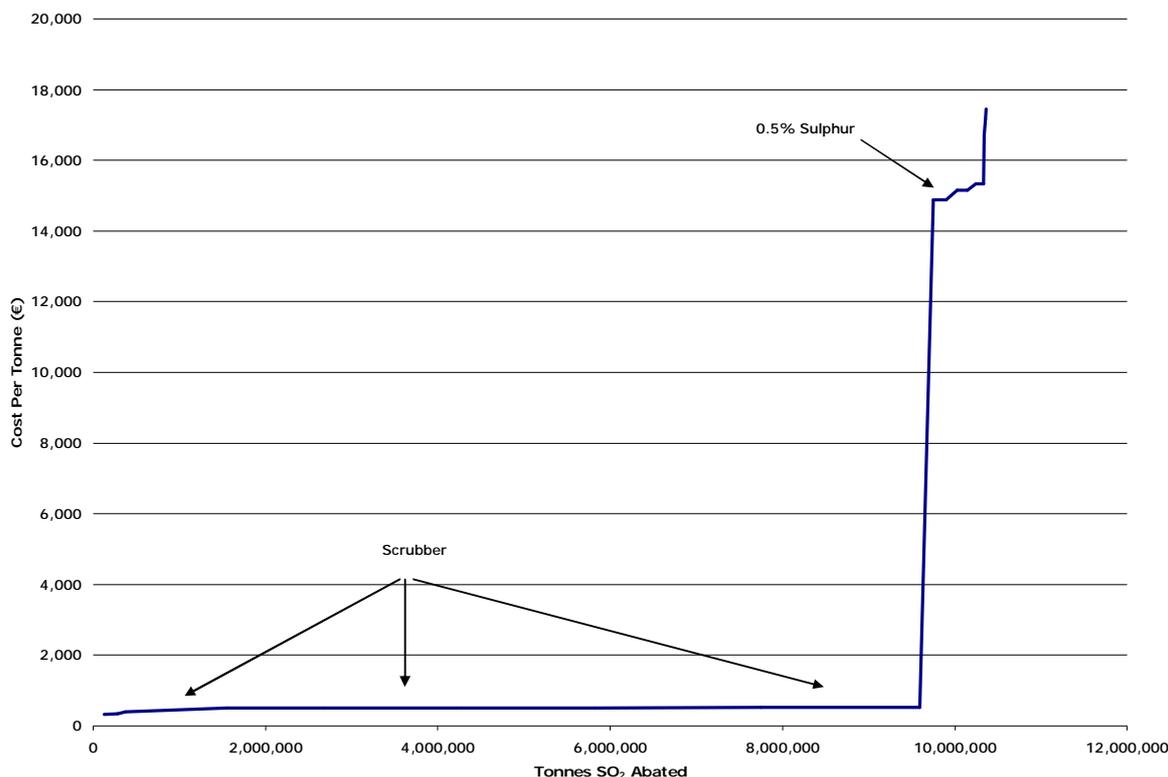


Source: NERA calculations.

6.3.3. Illustrative MACCs for SO₂ Emission Reductions

The following three figures present MACCs for SO₂ emission. Figure 6 shows the MACC for SO₂ if no information about geography or activity location were taken into account.

Figure 6. MACC for SO₂, No Geographical Considerations



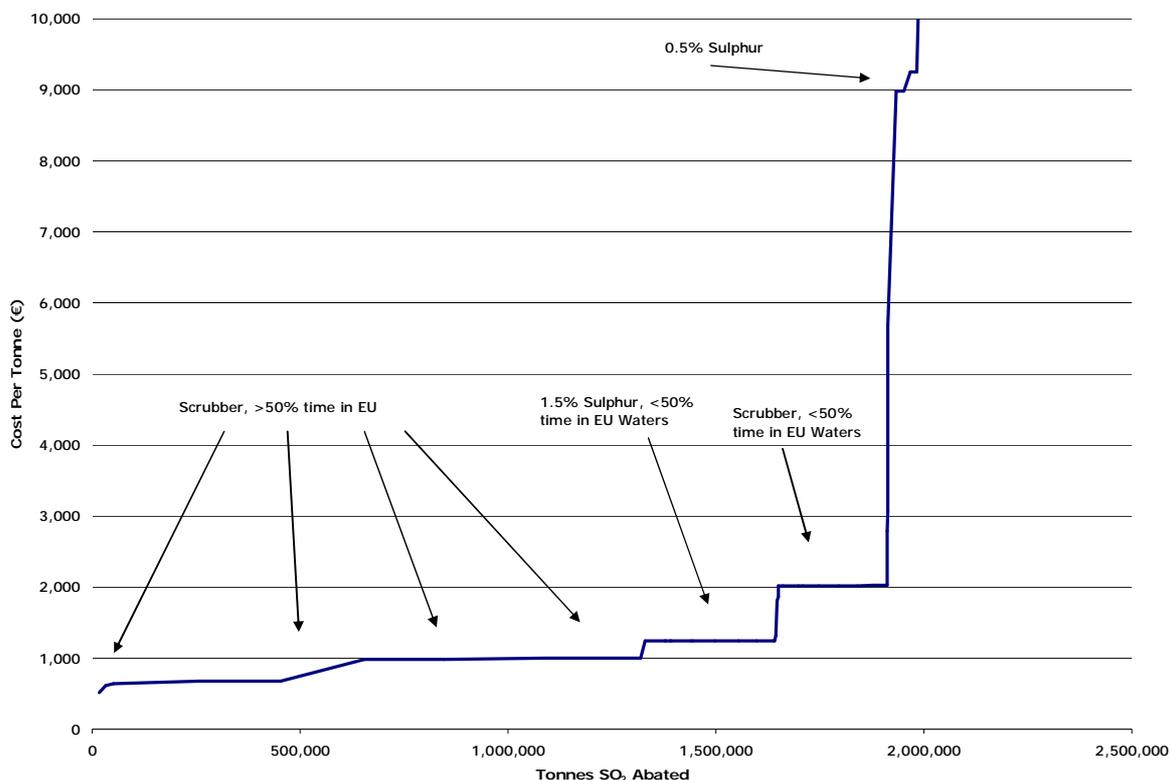
Source: NERA Calculations

Figure 6 indicates that if there are no geographical considerations scrubbers would make up the majority of the potential cost-effective reductions. This occurs due to the low variable cost of scrubbers compared to fuel switching, which makes it less expensive than switching all activity to 1.5 percent sulphur fuel and almost as effective at removing emissions as 0.5 percent sulphur fuel.⁴⁷ Since 0.5 percent sulphur fuel is slightly more effective at removing emissions, it makes up the final portion of the MACC, but the added *incremental* cost of using *only* 0.5 percent sulphur fuel causes the additional tonnes to be more than ten times as expensive as the per tonne cost of a scrubber.

Figure 7 shows the MACC for SO₂ when only emissions within 200 miles of EU coasts are considered, using the distribution assumptions shown in Table 13.

⁴⁷ The relative cost-effectiveness of scrubbing and fuel-switching could change for certain types of vessels under different assumptions. For example, the lack of information about of certain types of costs of fuel switching makes the option more attractive than it might otherwise be (see Footnote 41). Moreover, Entec has assumed that scrubbing can achieve SO₂ reductions on the order of 75 percent, but this estimate is conservative. It is possible that scrubbing could achieve greater reductions, which would increase its attractiveness relative to the fuel switching options. We have not assessed this latter possibility.

Figure 7. MACC for SO₂, EU 200-Mile Zone

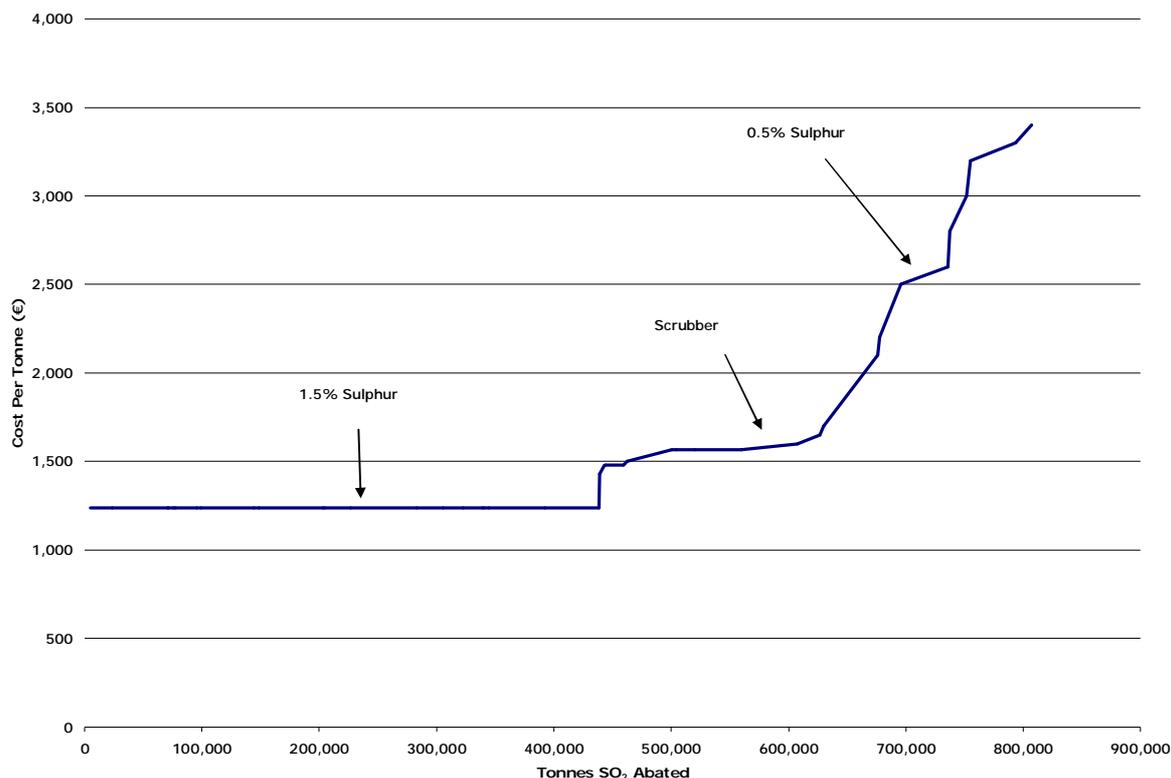


Source: NERA Calculations

Figure 7 shows that installing scrubbers on ships that spend the majority of their time in EU waters could provide over half the potential emissions reductions. For these vessels, a scrubber is more cost-effective on a per-tonne-reduced basis than switching to 1.5 percent sulphur fuel. For vessels that spend less than half of their time in EU waters, 1.5 percent sulphur fuel is slightly more cost-effective than a scrubber. At this level of activity Figure 8 also indicates that the additional tonnes reduced when a vessel switches to 0.5 percent sulphur fuel are still relatively expensive when compared to the per tonne cost of reductions from scrubbers.

Figure 8 shows the MACC for SO₂ when emissions in current SECAs are considered the only relevant emissions.

Figure 8. MACC for SO₂, SECA Zone

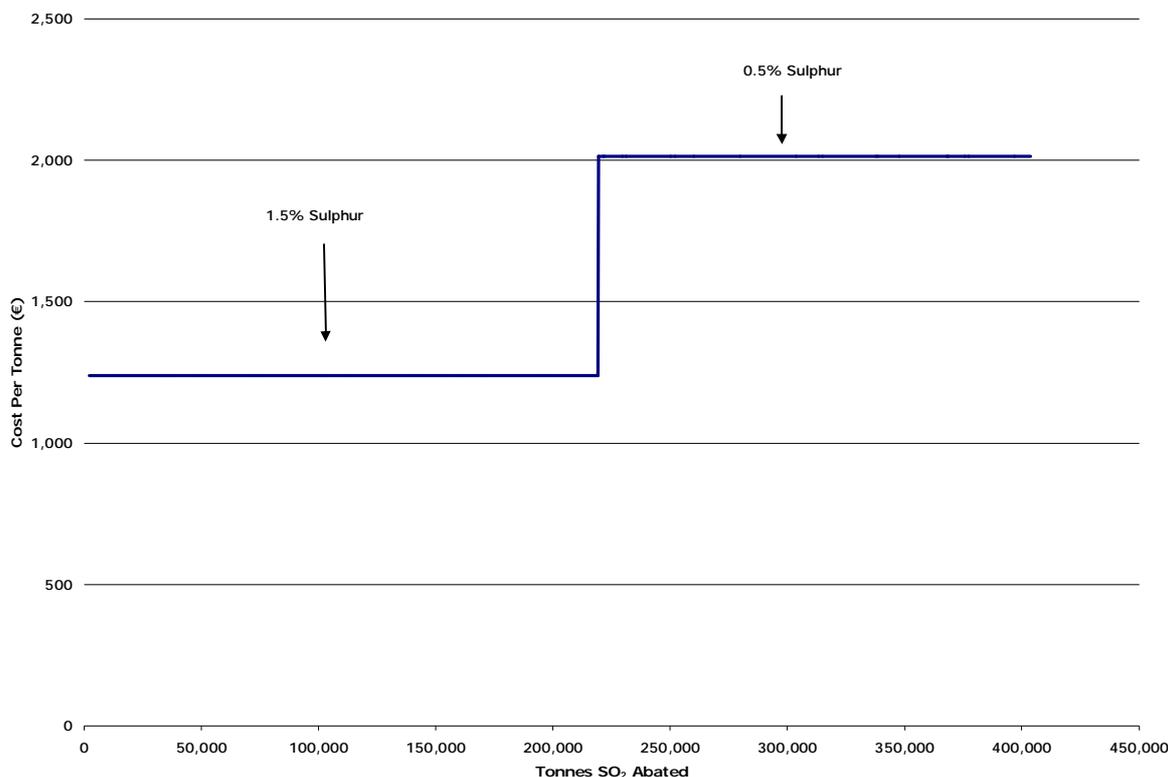


Source: NERA Calculations

Figure 9 shows the SO₂ MACC when emissions in the 12-mile zone are the only ones considered relevant. The difference between this curve and the MACCs for the 200-mile and the SECA zones is striking—if emissions in the narrower geographic region are the only focus of concern, scrubbing no longer appears to be an attractive abatement alternative. Given the activity distributions used here, the relevant activity across which the fixed costs of a scrubber can be spread is insufficient to make the technology preferable to a fuel-switching option. The variable-cost only strategy of using a lower sulphur fuel when in a 12-mile zone and using higher sulphur fuel elsewhere is significantly less expensive than incurring the fixed costs on installing a scrubber.⁴⁸

⁴⁸ Again, note that if data on the fixed costs and additional operating costs of adopting a dual-fuel approach had been available for our analysis it is possible that this conclusion would change for some vessel types.

Figure 9. MACC for SO₂, EU 12-Mile Zone

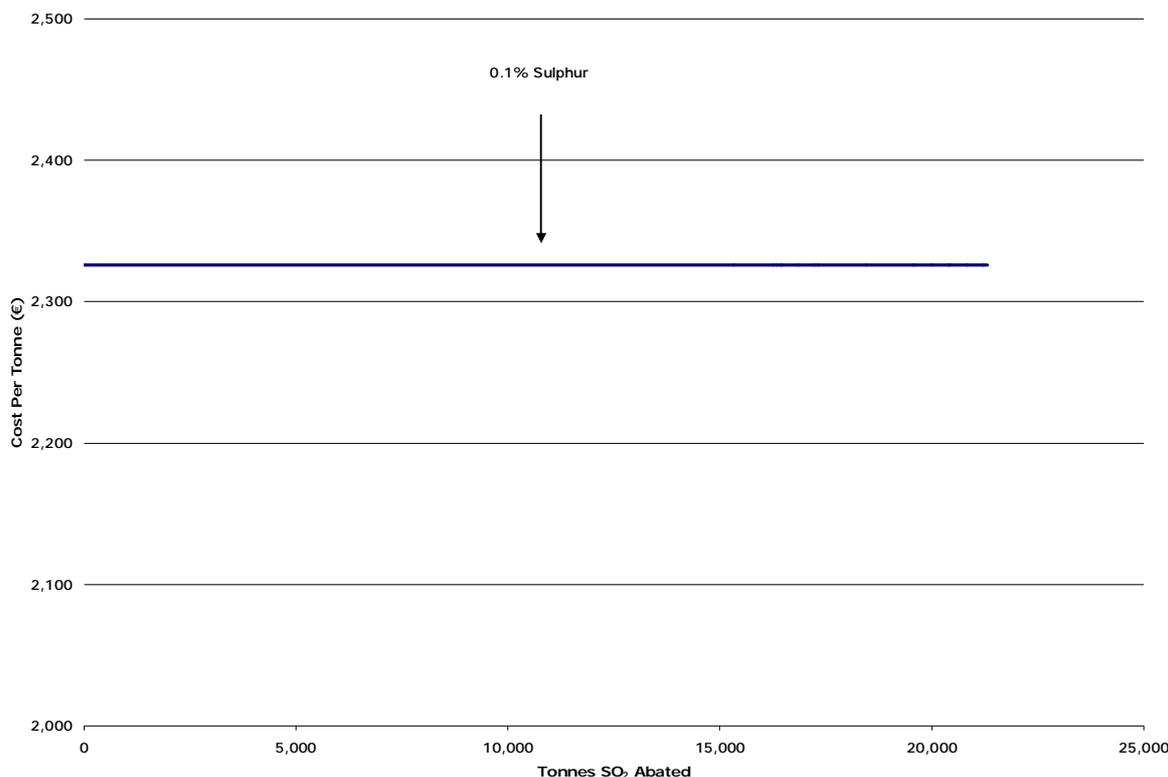


Source: NERA Calculations

Figure 10 shows the MACC for SO₂ when emissions while the vessel is at berth are the only type considered relevant. For this MACC, we consider either the possibility of using 0.1 percent sulphur fuel or shore power. As with other fuel switching alternatives, data on potential additional capital costs and on additional operating costs (apart from the fuel costs themselves) were not available, so the cost analysis may overestimate the attractiveness of the fuel switching option. However, as shown in Table 25, there is no SO₂ benefit when moving between 0.1 percent sulphur fuel and shore power. Therefore, since both reduce the same number of tonnes SO₂, and Table 27 indicates that 0.1 percent fuel is less expensive on a per tonne basis, only 0.1 percent fuel is shown in this figure.⁴⁹

⁴⁹ Note that the cost of shore power does not account for the co-benefits of NO_x reductions that result from using shore power. These benefits and associated cost-savings on other abatement measures would reduce the overall cost of using shore-side electricity to reduce SO₂. In addition, as noted above, costs for fuel switching do not include potential need for capital expenditure or non-fuel operating costs. These factors could potentially shift the balance for some vessels between the two alternative in-port options.

Figure 10. MACC for SO₂, At Berth Emissions Only



Source: NERA Calculations

6.4. Scenarios Considered

We use the data provided by Entec on vessel activity, emissions and technology costs to model the impact of different regulatory and market-based measures on reducing NO_x and SO₂ emissions. This section outlines the policy scenarios analysed.

6.4.1. NO_x Control Policy Scenarios

We have developed illustrative results for the following NO_x control policy scenarios. These are based on our own assumptions, and should not be taken as being indicative of likely future policy proposals.

§ *Regulatory.* In this scenario an emissions rate is set for NO_x that each vessel-type must meet, and all vessels are required to implement technologies to meet the corresponding rate. NERA has assumed that that all new ships will be required to reduce emissions 75 percent from BAU level and older ships will be required to reduce emissions 30 percent from BAU.

§ *Full Benchmark Trading.* In this scenario a fleet average emissions rate of 10.2 g/kWh⁵⁰ is set for NO_x, and all vessels are assumed to participate in a benchmarked emissions

⁵⁰ This is the emissions rate that results from the “Regulatory” scenario.

trading scheme. Although the assumption that all vessels participate in trading may not be feasible at present, it is useful as a point of comparison for other policy options. Each vessel is either awarded allowances if its emissions rate is below the average rate, or is required to purchase allowances if its emissions rate is above the average rate.⁵¹ The market price for emissions is computed that results in average emission rates equal to the policy target.

- § *Consortium Benchmark Trading.* In this scenario a fleet average NO_x emissions rate of 10.2 g/kWh is set for members of a trading consortium, but only ten percent of vessels are assumed to participate in trading via consortium membership. Consortium members must meet this average rate, and the emissions price is set internally to achieve this outcome. Other vessels must meet the requirements set by the Regulation policy.
- § *Regional Credit Trading.* In this scenario we assume an “external” price of NO_x credits applies to vessels with activity in some set of Member States or other region representing ten percent of total shipping activity. Each vessel then has the option to install technology that will reduce its emissions rate below 10.2 g/kWh (the same rate that would result from the regulatory case, or 30 percent below BAU levels). If the vessel reduces emissions below this threshold, it will receive credits for the additional reductions, which it can sell at the “external” NO_x price.⁵² We assume a range of “external” prices for NO_x and estimate the extent to which all vessels have incentives to reduce their emissions by offering emission reductions in exchange for credits at these prices.
- § *EU-wide Credit Trading.* Again, for purposes of comparison, we also assess a credit-based trading programme that applies across the EU, rather than in a particular Member State or region. The awarding of credits is modelled in the same manner as the regional credit trading scenario. We assume a range of “external” prices for NO_x and estimate the extent to which all vessels have incentives to reduce their emissions and generate emission reduction credits.

6.4.2. SO₂ Control Policy Scenarios

We have developed results for the following SO₂ emission scenarios.

- § *Regulatory.* NERA considered the following regulatory SO₂ scenario: require vessels to use 0.5 percent sulphur fuel when operating inside SECA waters and 1.5 percent sulphur fuel when operating inside all other EU waters, or alternatively apply an equivalent technical abatement option (i.e. scrubbing). This translates into a fleet-average emissions rate for SO₂ around 4.25 g/kWh.

⁵¹ The allowances are in tonnes of pollutant and are calculated as $Allowances\ (tonnes) = (Benchmark\ rate\ (g/kWh) - Vessel\ Rate\ (g/kWh)) * Activity\ (kWh) * 1\ tonne/1,000,000\ g$

⁵² The credits received by the vessel are calculated as $Credits\ (tonnes) = (10.2\ (g/kWh) - Vessel\ Rate\ (g/kWh)) * Activity\ (kWh) * 1\ tonne/1,000,000\ g$. Note that a vessel does *not* receive credits if its emissions rate is above 10.2 g/kWh.

- § *Full Benchmark Trading.* This scenario is similar to the full benchmarking one described for NO_x. In this scenario a target emissions rate of 4.25 g/kWh is set, and all vessels are assumed to participate in a benchmark trading scheme to meet this fleet average rate.
- § *Consortium Benchmark Trading.* This scenario is also similar to the one considered for NO_x. Ten percent of vessels are assumed to join a consortium, which can trade credits in order to achieve a consortium-wide emissions rate of 4.25 g/kWh or better, while vessels outside the consortium are required to follow the regulatory scenario.
- § *Regional Credit Trading.* In this scenario vessels receive credits for reducing emissions from activity occurring in a selection of Member States or a region comprising ten percent of total EU vessel activity. Vessels receive credits for all emissions reductions below a threshold of 20 percent below BAU levels. Credits are determined in a manner similar to the NO_x credit scenario, and can be sold at an “external price”. NERA considered a range of “external” SO₂ prices to estimate the effect different prices will have on a vessel’s incentive to reduce emissions.
- § *EU-Wide Credit.* This scenario is modelled in the same manner as the regional credit program, except all EU activity is considered relevant to receive credits.

6.5. Illustrative Policy Scenario Results

Using the data and assumptions described above, NERA was able to model the technological implementation for each vessel size and age under the scenarios described. All of the results below are approximations that are heavily dependent on our assumptions and should be viewed as illustrative.

6.5.1. Illustrative Results for NO_x Policies

Table 28 shows the impact of the various regulatory and market-based scenarios for NO_x in all sea areas using the EU water distributions, and compares these to the BAU values. (The results of the credit-based programme are shown in a separate table since they are not directly comparable to the other approaches being considered.) Note that, not surprisingly, the Full Benchmarking case has more cost savings and emissions reductions than the Consortium case (where only 10 percent of ships are assumed to participate).

Table 28. Emissions Impacts and Total Costs of Regulatory and Market-based NO_x Scenarios in All EU Sea Areas

	Units	BAU	Regulatory	Full Benchmark	Consortium Benchmark
Fleet Average NO _x Emissions Rate	g/kWh	13.32	10.16	9.82	10.12
Total NO _x Emissions	Million Tonnes	2.87	2.19	2.11	2.18
Total Cost of NO _x Controls	Million €	27	333	219	321
Average Cost Per Tonne Reduced	€/Tonne	N/A	489	291	467
Marginal Cost Per Tonne Reduced	€/Tonne	N/A	N/A	645	645
<i>Comparison to BAU</i>					
Additional NO _x Emissions Reductions	Million Tonnes	N/A	0.7	0.8	0.7
Additional NO _x Technology Costs	Million €	N/A	305	192	294

Source: NERA calculations.

Note: 1. As noted above, eligible young and new vessels, and some old vessels, are projected to be fitted with basic IEM under BAU.
2. BAU emissions levels differ slightly compared to Entec modelling due to rounding in NERA's distribution assumptions.

Table 28 indicates that the Full Benchmarking approach would yield 100 thousand tonnes more NO_x reductions than the Regulatory case, and would save more than €10 million compared to the Regulatory approach.⁵³ The Consortium Benchmarking approach, due to a smaller number of participating vessels, appears to yield only slightly greater emissions reductions, but would cost shipowners €10 million less than the Regulatory approach.⁵⁴

Table 29 shows the estimated impact of regional and EU-wide credit programme at three assumed credit prices. The table shows the estimated savings that could result if marine vessels were allowed to reduce their emissions in lieu of reductions at land-based sources, given different prices for emissions credits. These prices would reflect the underlying cost of abatement at land-based sources.⁵⁵ The results suggest that vessels could generate up to €202

⁵³ The allowance price for the benchmarking options is set to achieve a fleet average emissions rate less than 10.2 g/kWh. Because there are discrete classes of vessels, there is a significant drop in the fleet average emissions rate from 10.4 g/kWh to 9.2 g/kWh when the allowance price is increased from €644 to €645/tonne. This explains the significantly greater NO_x reductions in the benchmarking cases. If the data on vessel types and activity distribution were more detailed, the magnitude of the emissions over-achievement would likely decrease, as it would do in the real world. Therefore in assessing these results it may be more instructive to focus on the reduction in costs resulting from the trading approach than on the additional emissions reductions, although the prospect of lower costs may in turn make it significantly easier to agree on further emissions reductions.

⁵⁴ The results presented above, which indicate that technology costs from the benchmarking approach would be one-third less than costs from the regulatory approach, are dependent upon our age distribution assumptions, especially regarding the proportion of new vessels in the global fleet. We assume that four percent of the population are new vessels, which typically face lower capital costs for installing abatement technologies. Over time, an increasing number of vessels will have the option of being built with such technologies installed. If a larger proportion of the vessel population were able to install technology using the costs for new vessels, total costs of abatement could be reduced. For example, if as much as 20 percent of the fleet were eligible for "new build installation", technological uptake in the benchmarking case would be attractive to a larger number of vessels and costs would be less than half the costs under the regulatory case, rather than just one-third. Increasing the proportion of "new" vessels eventually may lead to a reduction in the difference between a flexible approach and a command and control one. This will depend on the relative requirements placed on new and old vessels under command and control and on the underlying heterogeneity of costs and abatement measures. If the regulations eventually lead to all vessels installing the maximum control technology, there will be little cost savings from market-based approaches. Under other circumstances, significant benefits may persist. All scenario results have assumed that four percent of vessels are new, but some results could change using different assumptions over time.

⁵⁵ Note that these estimates could understate the total cost savings since they do not account for reductions in the costs that would be incurred by land-based sources if they were required to abate emissions further. The average abatement cost for the residual land-based emissions could be higher than the marginal price of emissions credits.

million worth of savings in a regional credit trading scenario and up to €2.0 billion assuming EU-wide credit trading. Furthermore, the table shows that 220 thousand tonnes of credits could be generated in the regional trading scenario with as many 2.2 million credits from EU-wide credit trading.⁵⁶ (Note that the amount of savings from the benchmarking programmes and the credit programmes are *not* directly comparable, because the analysis of credit alternatives assumes that BAU policies include an existing land-based trading programme and associated costs, whereas the analysis of benchmarking programmes does not.)

Table 29. Implications of a NO_x Credit Programme under Different Credit Prices

	Units	Regional Credit Trading			Full Credit Trading		
		€500 / ton Credit	€1,000 / ton Credit	€1,500 / ton Credit	€500 / ton Credit	€1,000 / ton Credit	€1,500 / ton Credit
Fleet Average NO _x Emissions Rate	g/kWh	13.04	12.61	12.45	10.53	6.21	4.65
Total NO _x Emissions	Million Tonnes	2.81	2.71	2.68	2.27	1.34	1.00
Total NO _x Emissions Reduced	Million Tonnes	0.06	0.15	0.19	0.60	1.53	1.87
Total NO _x Credits Created	Million Tonnes	0.09	0.19	0.22	0.90	1.88	2.24
Total Value of NO _x Credits	Million €	45	188	336	449	1,878	3,358
Total Cost of NO _x Reductions	Million €	12	85	134	122	855	1,340
Net Savings	Million €	33	102	202	328	1,023	2,018

Source: NERA calculations.

6.5.2. Illustrative Results for SO₂ Policies

The tables in this section show a similar set of results for SO₂ as were shown for NO_x. We consider a case in which the “regulatory” scenario requires the use of 1.5 percent sulphur fuel or a scrubber in all EU seas excluding SECAs, where 0.5 percent sulphur must be used. For our analysis, the “BAU” scenario assumes that requirements are in line with the Marine Fuel Sulphur Directive, and therefore requires the use of 1.5 percent sulphur fuel in SECAs.

Table 30 show the effects of the various market approaches considered, relative to BAU and the Regulatory case. In fact the costs of fuel-switching are likely to be greater than is reflected here, because of additional costs associated with a “dual-fuel” compliance strategy that are not reflected in the analysis. The gains from market-based approaches come from the natural diversity of ships and abatement costs, which is only partly reflected in this illustrative data. Therefore the savings due to the alternative policy instruments considered here are likely to be greater than estimated.

⁵⁶ Note that because credits are awarded for emissions below a certain rate, the number of credits generated by a credit program will be less than the total emissions reduced by existence of the program.

Table 30. Emissions Impacts and Total Costs of Regulatory and Market-based SO₂ Scenarios

	Units	BAU	Regulatory	Full Benchmark	Consortium Benchmark
Fleet Average SO ₂ Emissions Rate	g/kWh	9.19	4.19	4.14	4.18
Total SO ₂ Emissions	Million Tonnes	1.98	0.90	0.81	0.89
Total Cost of SO ₂ Controls	Million €	506	2,036	1,452	1,978
Average Cost Per Tonne Reduced	€/Tonne	N/A	1,891	1,243	1,822
Marginal Cost Per Tonne Reduced	€/Tonne	N/A	N/A	1,244	1,244
<i>Comparison to BAU</i>					
Additional SO ₂ Emissions Reductions	Million Tonnes	N/A	1.08	1.17	1.09
Additional SO ₂ Technology Costs	Million €	N/A	1,530	946	1,472

Source: NERA calculations.

Note: BAU emissions levels differ slightly compared to Entec modelling due to rounding in NERA's distribution assumptions.

Table 30 indicates that the Full Benchmarking approach would yield almost 80 thousand extra tonnes of SO₂ reductions, while saving more than €500 million relative to the Regulatory approach. The lower participation in the Consortium Benchmark approach causes total emissions to be comparable to the Regulatory scenario, but shipowners would incur €50 million less in implementation costs.

Table 26 shows the effect on emissions and cost if the vessels are able to participate in a credit-based program at three representative prices for SO₂. Again, the cost savings under the benchmarking and credit-based trading approaches are not directly comparable.

Table 31. Implications of SO₂ Credit Programme under Different Credit Prices

	Units	Regional Credit Trading			Full Credit Trading		
		€500 / ton Credit	€1,500 / ton Credit	€2,500 / ton Credit	€500 / ton Credit	€1,500 / ton Credit	€2,500 / ton Credit
Fleet Average SO ₂ Emissions Rate	g/kWh	9.19	8.79	8.43	9.19	8.54	4.89
Total SO ₂ Emissions	Million Tonnes	1.98	1.89	1.82	1.98	1.86	1.07
Total SO ₂ Emissions Reduced	Million Tonnes	0.00	0.09	0.16	0.00	0.12	0.91
Total SO ₂ Credits Created	Million Tonnes	0.00	0.03	0.07	0.00	0.25	0.74
Total Value of SO ₂ Credits	Million €	0	38	185	0	381	1,852
Total Cost of SO ₂ Reductions	Million €	0	29	111	0	286	1,109
Net Savings	Million €	0	10	74	0	96	743

Source: NERA calculations.

Table 31 indicates that €743 million could be saved if external SO₂ prices reached as high as €2,500/tonne and all vessel activity was considered eligible to offset reductions required by land-based sources. If the credit program were confined to a smaller region, cost savings could still be valued at €74 million. Furthermore, regional credit trading could generate up to 70 thousand tonnes of credits and an EU wide program could create over 700 thousand tonnes of credits. However, this price is higher than what might reasonably be expected under a cap-and-trade programme for SO₂.⁵⁷ At lower SO₂ prices, the cost savings and emissions reductions would be lower.

⁵⁷ For comparison, the US Acid Rain Trading Program for SO₂ has in the past year seen record high prices for SO₂ on the order of \$900 / short ton—significantly lower than even our low end credit price scenario of €1,500 / metric tonne. Prices since 2003 have risen steadily from around \$200 to nearly \$900 per ton.

6.6. Summary of Illustrative Empirical Results

Our analyses suggest that the specific nature of vessel activity can have a significant impact on which technologies will be most cost effective. Similarly, the nature of the policy requirements, and in particular the region over which emissions are considered to be of concern, can also dramatically alter the incentives for installing particular technologies. This is reflected in the different shapes of the marginal abatement cost curves for different geographies and activity levels.

For NO_x , our analysis suggests that the approaches based on economic instruments can achieve greater emissions reductions at substantially lower cost than less flexible regulatory requirements. These results apply both for the benchmarking trading scheme as well as for the credit-based approach. The gains are of course smaller if only some vessels would be eligible to take advantage of the flexible policies, as would be the case in the consortium trading approach or the regional credit programme. The credit-based approach appears to show particular promise for NO_x , since it appears able to incentivise significant emissions reductions even in the absence of other regulatory requirements.

For SO_2 the flexible economic instruments also appear to generate comparable or slightly better environmental results at substantially lower cost compared to the less flexible alternative policies. Although the credit-based approach could offer significant incentives for operators to reduce emissions, the credit prices that would be required to do so may be higher than would be expected under a land-based trading scheme. This is in part due to the fact that existing regulations already require some emissions reductions, but may also simply reflect the relative cost of SO_2 reductions. For this reason it may be more feasible to achieve significant cuts in SO_2 via a benchmarking approach.

7. Conclusions

This report has provided considerable detail on four economic instrument policy approaches that might be applied to deal with emissions from the shipping sector. These analyses suggest some tentative conclusions regarding the role that such approaches might play in future regulation of emissions from ships. Our conclusions are in two categories.

We first provide updated assessments of the relative promise for the four approaches, considered separately for SO₂ emissions and NO_x emissions because of differences in their likely regulatory treatment (at least in the near term). We then provide tentative recommendations for the various design and implementation elements for two alternatives—one for SO₂ and one for NO_x—that appear to be particularly promising in the near term.

We emphasise that these conclusions and recommendations are tentative and preliminary for several reasons. First, many of the abatement technologies whose costs and effectiveness are assessed here are in very limited use, so the estimates of their costs and effectiveness are therefore still relatively uncertain. Second, both NERA and Entec have of necessity made various simplifying assumptions about vessel activity and compliance strategies to facilitate our analysis. Real world conditions are likely to be more complicated. Finally, our characterisations and recommendations for the individual parameters of the various economic instruments are also preliminary and in some cases have been chosen for illustrative purposes—setting different emissions baselines, for example, is likely to alter the results of different policies.

7.1. Conclusions Regarding the Relative Promise of the Four Instruments

This section provides summaries of our conclusions regarding the near term promise of each of the four economic instruments considered in the report. As noted, we provide separate assessments for SO₂ and NO_x.

7.1.1. Approaches for Controlling SO₂ Emissions from Ships

§ A credit-based approach for SO₂ could produce some cost-effective reductions, but only if the value of the credits were higher than previously observed. The following are details behind this conclusion.

- The Marine Sulphur Directive does provide the basis for setting a baseline for determining credits, resolving one of the often contentious aspects of credit-based approaches.
- Seawater scrubbing appears to offer cost-effective abatement for vessels with high activity in EU waters if emissions within a large region (e.g., 200 mile limit) were relevant for credits and if credit prices were high.
- However, because scrubbing can be more cost-effective than the use of low-sulphur fuels, credits based upon scrubbing could represent “anyway tonnes” since in principle the regulations already permit scrubbing to be used to meet emissions levels.

- The allowance prices necessary to incentivise abatement—using either scrubbers or low sulphur fuel—are higher than the prices observed under existing trading programmes.
- Monitoring emissions would add to the cost of the credit approach, which could increase the overall cost of using a scrubber and thus increase the prices that would have to be established for viable credits. (However, emerging IMO guidelines on scrubbing suggest that for some ships continuous monitoring may be required in any case)

§ The consortium benchmarking approach appears to offer advantages relative to a “command-and-control” requirement that all ships use low-sulphur fuels. The following are details behind this conclusion.

- Allowing ship owners/operators to form consortia and use any mix of SO₂ controls (1.5 percent sulphur, 0.5 percent sulphur, or sea water scrubbers) could lead to an average emission rate below the level that would be achieved with a universal requirement to use low-sulphur fuels.
- The flexibility provided by benchmarking would lead to substantial reductions in control costs. Based on estimates of vessel activity, the cost under benchmarking could be 35 percent less than the cost of achieving the same emissions levels via the use of low-sulphur fuels alone. If other costs of fuel-switching were accounted for the cost savings are likely to be greater.
- Administrative procedures could be developed at reasonable cost to establish a consortium benchmarking programme.
- Reliable and relatively low-cost monitoring protocols could be developed to monitor SO₂ emissions and determine whether ships are achieving the emission rates in their compliance plans.
- Because the “regulatory” approach already provides some flexibility to use alternatives to low-sulphur fuel (i.e., sea water scrubbing), the cost savings from benchmarking are reduced, but they still appear to be significant.

§ The voluntary port dues programme appears less promising than the consortium benchmarking approach as a means of generating substantial reductions in SO₂ emissions from ships in the near term, unless a concerted effort were made to coordinate efforts among ports. The following are the specifics behind this conclusion.

- Existing port dues programmes provide evidence that programmes may generate some localised emissions reductions.
- However, the incentive provided by individual port action may be insufficient to induce substantial emissions reductions for most vessels.

- Responses from ports indicate that they are reluctant to differentiate their own dues for fear that it would place them at a disadvantage relative to competitors.
- Thus, port dues would require close coordination among ports to provide sufficient incentive for a substantial number of ships to undertake costly efforts to reduce SO₂ emissions. At least in the near term, such coordination seems unlikely to arise because of competition between ports.
- The longer-term possibility of port coordination could be encouraged, however, through efforts to publicise the programme and assist in the development of standardised protocols for major elements.
- A more coordinated effort to apply infrastructure charges to a wider geographical range than individual ports—following on the apparent success of the Swedish fairways programme—may be a more promising alternative in the medium term.

§ The environmental subsidy approach—either as a stand-alone programme or an environmental modification of an existing subsidy—does not appear to be a promising means of reducing SO₂ emissions from ships. The following are the bases for this conclusion.

- A stand-alone subsidy programme could be developed to pay for emission reductions below those required by the sulphur fuel directive, using a structure similar to that of the credit-based approach. However, there is no apparent source for the monies that would be required to provide incentives to generate “credits.”
- As noted above, the cost per tonne to incentivise “credit-based” SO₂ reductions from ships appear high, and thus the subsidy would have to be large to generate significant SO₂ reductions.
- Modifying the existing EU subsidy programme for ship building to include an environmental component—for example, requiring the installation of a sea water scrubber—would effectively reduce the net subsidy for other shipbuilding activities and thus could reduce the support objectives served by the existing subsidy programme.
- Subsidies could be used to help defray the costs of existing or proposed policies to reduce emissions.
- Commission initiatives such as Marco Polo and Motorways of the Sea, which fund marine infrastructure and modal shifts, could include stronger environmental components in their funding criteria. If the EC allocated approximately 10 percent of planned funds for Marco Polo II, or €10 million annually, to the most cost-effective projects to improve air quality, this could create incentives to reduce 16,000 tonnes of SO₂ a year. Alternatively, the funds could be used to offset ports’ cost of upgrading berths to permit use of shore-side electricity. Based on

Entec's (2005b,c) estimates, this annual amount could offset the costs of upgrading between 150-350 berths for the use of shore power.⁵⁸

7.1.2. Economic Instruments for Controlling NO_x Emissions from Ships

§ The credit-based approach appears more promising for NO_x than for SO₂. The following are the reasons for this conclusion.

- Many emission control alternatives are available to reduce NO_x from ships, with a wide range in cost per ton.
- Based upon preliminary cost information, a substantial number of NO_x credits would be available at NO_x allowance prices in a likely range under a cap-and-trade programme for large stationary sources.
- Although there is no regulatory baseline for NO_x credits equivalent to the Sulphur Directive, a reasonable baseline should be relatively straightforward to develop based upon the IMO NO_x curve (presumably modified to provide some environmental benefits relative to business as usual).
- Monitoring would be feasible for NO_x, based upon methods that monitor ship activity and sample emission rates.
- Other design and implementation features could be developed to define a feasible credit-based programme for NO_x.

§ The consortium benchmarking approach would offer environmental and economic gains relative to a less flexible command-and-control regulatory requirement; but the lack of a likely near term NO_x requirement for ships suggests the benchmarking approach may be less attractive for the near term than a credit-based approach for NO_x. The following are the bases for this conclusion.

- A benchmark level for the consortium could be set based upon the IMO NO_x curve, perhaps modified as in the credit-based approach to ensure some environmental benefits relative to BAU.
- The flexibility provided by consortia benchmarking would lead to significant reductions in control costs relative to the requirement that all ships achieve the same emission rate. Based on estimates of vessel activity, the cost under benchmarking could be 45 percent less than the cost of achieving the same emissions levels achieved under a regulatory requirement.
- Administrative procedures could be developed at reasonable cost to establish a consortium benchmarking programme for NO_x.

⁵⁸ Note that this assumes Marco Polo funding levels would be extended for the full period required to recover the capital expenditures of installing shore-side electricity. Taking into account only the funds currently allocated, a ten percent set-aside for shore-side electricity would pay for between 60 to 230 berths.

- Monitoring protocols for NO_x would be more expensive than for SO₂. In many cases, such protocols probably would also be required for a traditional regulatory programme for NO_x, and thus the added costs of allowing consortia benchmarking would be modest.

§ The voluntary port dues programme appears less promising than other approaches as a means of generating substantial reductions in NO_x emissions from ships in the near term. Local benefits may be achieved, but broader benefits would require coordination that may be difficult to achieve at the port level. The bases for this conclusion are the same as for SO₂ emissions:

- Existing port dues programmes do provide evidence that the programme can generate localised emissions reductions, but these typically have been implemented in conjunction with dues differentiation applied to a wider area.
- The incentive provided by individual port action may be insufficient to induce substantial changes in behaviour for most vessels.
- Responses from ports indicate that they are reluctant to differentiate their own dues for fear that it would place them at a disadvantage relative to competitors.
- Port dues would require coordination among ports to provide sufficient incentive for a substantial number of ships to undertake costly efforts to reduce NO_x emissions. At least in the near term, such coordination seems unlikely to arise.
- The longer-term possibility of port coordination could be encouraged, however, through efforts to publicise the programme and assist in the development of standardised protocols for major elements.
- A more coordinated effort to apply infrastructure charges to a wider geographical range than individual ports—following on the apparent success of the Swedish fairways programme—may be a more promising alternative in the medium term.

§ The environmental subsidy approach appears to be less promising than other approaches as an independent means of reducing NO_x emissions from ships. The following are the reasons for this conclusion, which are similar to those for SO₂ emissions..

- No source is apparent for the monies that would be required to provide incentives to adopt NO_x reductions as a stand-alone subsidy programme.
- Modifying the existing EU subsidy programme for ship-building to include an environmental component—for example, requiring the installation of a sea water scrubber—would effectively reduce the net subsidy for other shipbuilding activities and thus could reduce the support objectives served by the existing subsidy programme. If these industries are marginal then additional funding would be required to sustain them.

- Subsidies could be used to help defray the costs of existing or proposed policies to reduce emissions.
- Commission initiatives such as Marco Polo and Motorways of the Sea, which fund marine infrastructure and modal shifts, could include environmental components in their funding criteria. If the EC allocated approximately 10 percent of planned funds for Marco Polo II, or €10 million annually, to the most cost-effective projects to improve air quality, this could create incentives to reduce 224,000 tonnes of NO_x. Alternatively, these funds could be used to offset the cost ports would incur to install shore-side electricity.

7.2. Conclusions Regarding Design and Implementation Elements for Selected Promising Economic Instruments

This section summarises tentative conclusions regarding the design elements and implementation elements for the two economic programmes that appear particularly promising: (1) a consortium benchmarking approach for SO₂; and (2) a credit-based programme for NO_x.

7.2.1. Consortium Benchmarking Programme for SO₂

Based upon our review, the following are tentative conclusions regarding the design and implementation elements for a consortium benchmarking approach for SO₂.

7.2.1.1. Design elements

7.2.1.1.1. Participation in the consortia

- § No restriction would be placed on the location of vessel activity potentially covered by a benchmarking consortium (although as discussed below, only emissions within a given geographic area would be relevant for the programme).
- § No restrictions would be placed on the type/size of vessel that could participate.
- § Vessels from EU Member States would be eligible, as would other flagged ships if they agree to be bound by the relevant regulations.
- § Restrictions on “standing” of vessel and/or owner could be imposed at the discretion of the consortium, and authorities may wish to monitor the development of “standing” requirements to ensure they are satisfied with them.

7.2.1.1.2. Covered pollutants and incentivised measures

- § Sulphur dioxide emissions would be covered directly by the programme. (The programme may generate “co-benefits” but other emissions would not be included.)
- § Because the benchmark trading programme would be defined in terms of emissions per unit of input (as detailed below), it would not provide incentives to increase vessel fuel efficiency.

7.2.1.1.3. *Baseline emission rates*

- § The baseline emission rate would be linked to the Sulphur Directive, reduced by a fixed percentage to ensure environmental gains. It may be important to assess further whether reductions that would be achieved anyway because of the use of scrubbers could be “diluted” by averaging with other consortium participants.
- § Alternatively, a more stringent “baseline” could be set that would provide emissions in line with a 1.5 percent sulphur requirement in all EU waters and a 0.5 percent sulphur requirement in SECAs.

7.2.1.1.4. *Geographic differentiation*

- § Separate trading areas would be established for the regions identified under the Sulphur Directive.
- § Individual ships could participate in multiple consortia corresponding to these identified regions.

7.2.1.1.5. *Banking*

- § Banking would be allowed, i.e., consortia members would be allowed to “save up” surplus allowances to be used in the future to offset their own emissions or to sell to other members.

7.2.1.1.6. *Legal and institutional elements*

- § Legal responsibility for achieving the benchmark would be with the individual ship owner, as it is under the Sulphur Directive. Recourse for activities of other consortium members that interfere with compliance—or make compliance more costly—for an individual member would be through private actions.
- § Consortium members would need to develop legal and institutional arrangements governing entry and exit that prevent exit during a given commitment period.

7.2.1.2. Implementation elements

The following are tentative conclusions/recommendations regarding implementation elements, i.e., features that come into play as the programme is implemented.

7.2.1.2.1. *Permitting and verification*

- § No process is needed to certify allowances—beyond the monitoring of emissions, as noted below. The baseline for credits and debits is the emission level equivalent to the requirements of the Sulphur Directive, taking into account the lower rate provided for consortia as a means of providing environmental benefits in exchange for the cost-saving flexibility.
- § Verification would consist of ensuring that the participating vessels collectively met the benchmark rate.

§ Initially, submissions would be required on a quarterly basis, to ensure that sufficient procedures were in place and to provide interim reporting. As noted below, compliance would be determined on an annual basis.

7.2.1.2.2. Monitoring and reporting

§ Monitoring requirements would include detailed monitoring of vessel position and would also depend on whether a sea-water scrubber was in place and, if so, on the size of the ship.

- For ships without a sea-water scrubber (or other emission control equipment), monitoring would be based upon a tamper-proof fuel meter supplemented by verified receipts showing the sulphur content of the fuel used (for each separate fuel tank on board).
- Ships using abatement equipment (such as a sea-water scrubber) also would be required to obtain information on their average SO₂ emission rate from a qualified third-party environmental audit firm.

§ If a programme audit revealed inaccuracies in these emissions data, larger vessels would be required to install a continuous emissions monitor to sample SO₂ concentration and to measure gas flow using CO₂ concentrations as an index of fuel use.

7.2.1.2.3. Compliance and enforcement

§ Compliance would be determined on an annual basis, based upon submissions of reports from individual consortium members.

§ An annual compliance period would be established (e.g., 1 January to 31 December or 1 July to 30 June), with a 30-day “true up” period allowed for individual consortium members of trade credits among themselves or draw down banked allowances

§ Enforcement would consist of taking actions against individual members with a negative allowance balance at the end of the true up period, i.e., emissions in excess of credits.

§ Penalties for non-compliance would be assessed against individual ship owners, with the penalties consisting of reductions in future year credits on some basis (e.g., 2 tons lost for every ton excess of the allowable level) as well as a financial penalty. There could be implications for consortia if members were found repeatedly to be in breach.

§ Enforcement could be supplemented by periodic “random” inspections of ships to check emissions rates and fuel use. If there was evidence that monitoring and reporting were not accurate, penalties would be assessed

7.2.1.2.4. Programme administration

§ Most of the programme administration would be the responsibility of the consortium members, who would develop guidelines for transactions, arrange for third-party verifiers where required and otherwise organise the consortium.

§ Government agencies would have the responsibility of developing membership guidelines for consortia, vetting protocols, and enforcing the programme. Note, however, that many of the programme administration elements would be common to those required under the Sulphur Directive.

7.2.2. Credit-Based Programme for NO_x

Based upon our review, the following are tentative conclusions regarding the design and implementation elements for a credit-based programme for NO_x.

7.2.2.1. Design elements

7.2.2.1.1. *Participation in the programme*

§ No restriction would be imposed on the location of vessel activity (although as discussed below, only emission reductions within a given geographic area would be eligible for credits).

§ No restrictions would be imposed on the type/size of vessel that could participate.

§ EU vessels as well as other flagged ships would be eligible to participate if they met the requirements of the programme.

7.2.2.1.2. *Covered pollutants and incentivised measures*

§ NO_x emission reductions would receive credits directly. (The NO_x credits may yield “co-benefits” but credits would not be developed for other emissions.)

§ The programme would provide incentives to reduce NO_x emissions using a large number of possible pollution control technologies (e.g., SCR, HAM) as well as by changes in the engine (e.g., engine modifications, installing a new engine).

§ Because the programme would base credits on the emission *rate*—rather than total NO_x emissions—the programme would not provide incentives to reduce NO_x emissions by improving fuel efficiency.

7.2.2.1.3. *Baseline determination*

§ The baseline for each ship’s emission rate could be based upon the IMO NO_x curve, perhaps “shifted” (i.e., lowered by a given percentage) to reflect some additional environmental benefit.

7.2.2.1.4. *Geographic differentiation*

§ Credits would be provided for emission reductions in a broad geographic area determined to be relevant for air quality and exposure and linked to the existing trading scheme. This could be on a global basis (through the International Maritime Organization), a regional basis (through the European Union), or on a national or local basis.

7.2.2.1.5. *Banking and sunset*

- § Credits developed from reductions in NO_x shipping emissions could be banked to the extent allowed by the relevant cap-and-trade (or other regulatory programme) for NO_x.
- § The credit based programme would be reviewed (“sunset”) using the same timetable as for the relevant cap-and-trade (or other regulatory programme) for NO_x.

7.2.2.1.6. *Legal and institutional elements*

- § The cap-and-trade programme for NO_x would need to provide for the use of credits generated by vessels under this credit-based programme.

7.2.2.2. Implementation elements

The following are tentative conclusions/recommendations regarding implementation elements, i.e., elements that arise primarily as the programme is implemented.

7.2.2.2.1. *Permitting and verification*

- § Credits would be verified by third party verifiers—engaged by the ship owner participating in the programme—who would be overseen by the government. Classification societies have performed this kind of role in other maritime legislation.
- § Emission reduction credits would be calculated as the difference between verified emissions over the relevant period (e.g., one quarter) minus baseline emissions over the same period.
- § Credits would be issued after they are verified, i.e., after the third-party verifier calculates emissions reductions.

7.2.2.2.2. *Monitoring and reporting*

- § Monitoring would be designed to develop estimates of average NO_x emission rates comparable to those in the IMO NO_x curve.
- § Monitoring equipment would be required to provide information on location, NO_x emission rates, CO₂ emissions (as measures of fuel use), and engine parameters.
- § Reporting would consist of information on baseline emissions (i.e., emissions assuming the baseline NO_x curve or its more stringent counterpart), actual emissions during the period (e.g., quarter), and the resulting NO_x reduction credits.

7.2.2.2.3. *Compliance and enforcement*

- § Compliance would consist of verifying that the actual emissions reported to obtain NO_x credits were accurate. This might include the possibility of random checks of the information provided.

- § Enforcement would consist of taking actions against those whose actual emissions were greater than the verified emissions used to calculate credits.
- § Penalties for excessive emissions (and thus excessive emission reduction credits) would consist of fines based upon the extent of the exceedance and the reason (e.g., error by third-party verifier versus tampering with equipment).

7.2.2.2.4. Programme administration

- § Government administration would be required to develop the basic programme guidelines, certify credits (based upon submissions of third-party verifiers), specify the required monitoring techniques, and enforce the programme.
- § Government administration also may be required to develop random checks of ships' emissions if that were part of the compliance/enforcement programme.

8. References

- Asplund, Lars. 1999. "Infrastrukturavgifter inom sjöfarten – nuläge och möjliga alternativ" ("Infrastructure Dues for Shipping – Current Status and Possible Alternatives"). In Swedish.
- BMT Murray Fenton Edon Liddiard Vince Limited. 2000. "Study on the Economic, Legal, Environmental and Practical Implications of a European Union System to Reduce Ship Emissions of SO₂ and NO_x," Report No. 3623, Appendix 3.
- Coast Guard Navigation Center. Universal Shipborne Automatic Identification System. URL: <http://www.navcen.uscg.gov/marcomms/ais.htm>.
- California Air Resources Board ("CARB"). 2004. "Proposed Measure for Auxiliary Diesel Engines Operated on Oceangoing Ships in California Coastal Waters." Draft Proposal for Discussion Only at November 10, 2004 Workshop.
- California Air Resources Board ("CARB"). 2005. "Proposed Measure for Auxiliary Diesel Engines Operated on Oceangoing Ships in California Coastal Waters." Draft Proposal for Discussion Only at May 18, 2005 Workshop.
- Eckerle, Ed. 2005. Conversation with NERA. 18 March.
- ECORYS Transport. 2004. *Ex Ante Evaluation. Marco Polo II (2007-2013)*. Final Report 1. Rotterdam. 15 June.
- Ellerman, A. Denny, Paul L. Joskow and David Harrison, Jr.. 2003. *Emissions Trading in the U.S.: Experience, Lessons, and Considerations for Greenhouse Gases*. Arlington, Va.: Pew Center on Global Climate Change, May.
- Ellerman, A. Denny, Paul L. Joskow, Richard Schmalensee, Juan-Pablo Montero, and Elizabeth M. Bailey. 2000. *Markets for Clean Air: The US Acid Rain Programme*. Cambridge: Cambridge University Press.
- Entec UK Limited. 2002. "Quantification of emissions from ships associated with ship movements between ports in the European Community." European Commission. July.
- Entec UK Limited. 2005a. "Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 1 – Preliminary Assignment of Ship Emissions to European Countries." European Commission. August.
- Entec UK Limited. 2005b. "Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 2 – General Report." August.
- Entec UK Limited. 2005c. "Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 2a – Shore-side Electricity in Ports." August.

- Entec UK Limited. 2005d. "Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 2b – NO_x Abatement Technologies." August.
- Entec UK Limited. 2005e. "Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 2c – Sea Water Scrubbing." August.
- European Association of Internal Combustion Engine Manufacturers. 2002. "Legislation of Exhaust Emissions from Commercial Marine CI Engines: Euromot Proposal for Regulatory Alignment."
- European Commission ("EC"). 1998. "Fair Payment for Infrastructure Use: A phased approach to a common transport infrastructure charging framework in the EU." White Paper. COM(1998) 466. 22 July.
- European Commission ("EC"). 2001. "European transport policy for 2010: time to decide." White Paper. 12 September.
- European Commission ("EC"). 2003a. "Proposal for a Directive of the European Parliament and of the Council amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures." COM(2003) 448. 23 July.
- European Commission ("EC"). 2003b. "Transport infrastructure charging policy." http://europa.eu.int/comm/transport/infr-charging/charging_en.html. Updated 24 July.
- European Commission ("EC"). 2004. "Proposal for a Regulation of the European Parliament and of the Council establishing the second 'Marco Polo' programme for the granting of Community financial assistance to improve the environmental performance of the freight transport system ('Marco Polo II')." 14 July.
- European Commission ("EC"). 2005. "Marco Polo – Call 2003. Best 19 Projects out of a Total of 92 Projects Submitted. Subset of 13 Projects (of 19 best) finally contracted." Last updated 4 February.
- GAUSS. 2001. Entwicklung eines Modells für ein integratives und international einsetzbares Bonussystem Quality Shipping – Ergebnisse der Studie (Development of a Model for an Integrated and Internationally Adoptable Bonus System, "Quality Shipping" – Results of the Study). In German. Bremen: GAUSS. October.
- Harrison, David. 2002. "Tradable Permit Programs for Air Quality and Climate Change," in *International Yearbook of Environmental and Resource Economics*, Volume VI, Henk Folmer and Thomas Tietenberg (Eds.). London: Edward Elgar, 2002.
- Harrison, David. 2003. "Ex Post Evaluation of the RECLAIM Emissions Trading Program for the Los Angeles Air Basin." Prepared for the National Policies Division, OECD Environment Directorate, June.
- Harrison, David, S. Todd Schatzki, with Thomas Wilson and Erik Haites. 2000. *Critical Issues in International Greenhouse Gas Emissions Trading: Setting Baselines for*

- Credit-Based Trading Programs-Lessons Learned from Relevant Experience*. Palo Alto, CA, Electric Power Research Institute, June.
- Hirst, David. 2002a. "Emission Reductions Trading for Shipping." Shipping Emissions Abatement and Trading ("SEAA"). 8 December.
- Hirst, David 2002b. "Which Emissions Reductions Should Shipping Trade." (SEAA). 8 December.
- International Marine Organisation ("IMO"). 2000. "Study of Greenhouse Gas Emissions from Ships." IMO. 31 March.
- International Marine Organisation ("IMO"). 2003. "Implications of the United Nations Convention on the Law of the Sea for the International Marine Organization." IMO. 6 January.
- International Organization for Standardization. ISO 14000. ISO and the Environment. http://www.iso.org/iso/en/iso9000-14000/basics/basics14000/basics14000_1.html.
- IVL. 2005. "EU service contract on ship emissions: assignments, abatement and market-based instruments." Prepared for Entec UK, Ltd. by David Cooper. 12 April.
- Kågeson, Per. 1999. "Economic instruments for reducing emissions from sea transport."
- Lemieszewski, S. 1998. "The Recently Introduced Swedish Incentive of Differentiated Fairway and Harbour Dues for Ships Related to their Environmental Impact." (Cited in BMT 2000, Appendix 3, p. 11.)
- Maennig, W. and M. Sames. 2000. "Determinanten der Seehafenwahl." *Zeitschrift für Verkehrswissenschaft*. (Cited in GAUSS 2001.)
- MariTerm. 1999. "Utvärdering av miljödifferenterade avgifter för sjöfarten" ("Evaluation of environmentally differentiated maritime charges"). In Swedish. December.
- MariTerm. 2000. "Förstudie inom området miljöindex för sjöfart" ("Feasibility Study on an Environmental Indexing for Shipping").
- Murlis, John. 2003. Conversation with NERA. 23 July.
- NERA. 2004. Harrison, David, Jr., Daniel Radov, and James Patchett. *Evaluation of the Feasibility of Alternative Market-Based Mechanisms to Promote Low-Emission Shipping in European Union Sea Areas*. London: National Economic Research Associates. March.
- Sarkar, Dipankar. 2005. Conversation with NERA. 15 March.
- Shipping Emission Abatement and Trading ("SEAA"). nd. "SOX – Sulphur Offsetting eXperiment: An emissions trading scheme for shipping." Concept Paper.

- Stavins, Robert N. 2000. "Experience with Market-Based Environmental Policy Instruments." Discussion Paper 00-09. Washington, D.C.: Resources for the Future.
- Swahn, Henrik. 2002. "Environmentally differentiated fairway charges in practice—the Swedish experience." European Commission.
- Swedish Maritime Administration ("SMA"). 2000. "Översyn av Farledsavgifterna" ("Overview of Fairway Dues"). In Swedish.
- Swedish Maritime Administration ("SMA"). 2002a. "Luftmiljö – Avgasemissioner från Sjötrafiken" ("Air Environment – Airborne Emissions from Sea Traffic"). In Swedish. October.
- Swedish Maritime Administration ("SMA"). 2002b. *Annual Report*. Stockholm: SMA.
- Swedish Maritime Administration ("SMA"). 2003. *Annual Report*. Stockholm: SMA.
- Swedish Maritime Administration ("SMA"). 2004. "Sjöfartsverkets föreskrifter om farledsavgift" ("SMA's Statutes on Fairway Dues"). SJÖFS 2004:26. 8 December.
- Swedish Maritime Administration ("SMA"). nd. "Environmentally Differentiated Fairway and Port Dues."
- Swedish Ports and Stevedores' Association. 1996. "Recommendation concerning environmentally differentiated charging in ports." 22 October.
- Tostmann, Stefan. 2004. "Motorways of the Sea." Consultation Meeting. 29 November.
- United States Environmental Protection Agency ("US EPA"). 2004. "International Experience with Economic Incentives for Protecting the Environment." November.

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