

Market-Based Approach for Improving Ship Air Emissions

by

Matthew Donatelli

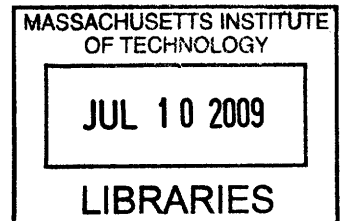
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Abstract

This study considered how appropriate different market-based approaches are for the reduction of ship air emissions, particularly CO₂. Furthermore, the study also considered which types of market-based tools may be available for application to the shipping industry. This project was not intended to design or optimize a system for the maritime community.

The study considered the current input and discussions within the International Maritime Organization and its Marine Environment Protection Committee and identified three major thought patterns in proposed systems for the maritime industry: (1) an emissions trading scheme for the shipping industry, (2) CO₂ indexing, and (3) alternative approaches. The most significant alternative approach is to place a levy on fuel bunkers. Other alternative approaches could involve hybrid systems using any combination of the other systems mentioned.

The study identified a number of unresolved issues and tradeoffs that could hinder the implementation of these systems. These industry-specific issues include technical, policy, administrative, and infrastructure considerations. Currently, there is no consensus on which type of system to use or even whether any of these systems will be used. The study concludes with recommended steps towards emissions management for ship owners and operators.

Thesis Supervisor: Henry S. Marcus
Title: Professor of Marine Systems

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Executive Summary

The objective of this study was to consider how appropriate different market-based approaches are for the reduction of ship air emissions, particularly CO₂. Furthermore, the study also considers which types of market-based tools may be available for application to the shipping industry. This project was not intended to design or optimize a system for the maritime community. For this study, the author has loosely defined market-based system to mean a system which implements economic incentives to prompt reduction in air emissions.

The report first reviews the background information and motivation in an abbreviated manner and has addressed only the information which was considered directly relevant and prerequisite to understanding the remainder of the report. Subsequently, the study investigated market-based tools that are used in other industries, existing systems and efforts in the maritime industry, and proposed systems and ideas for the maritime industry. This investigation is followed by a discussion of the major unresolved issues for the application of a market-based system to the shipping industry. The study ends by drawing a number of conclusions and some steps towards emissions management are suggested in the final chapter of the report.

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) stirred up discussion of reducing greenhouse gas (GHG) emissions. This eventually led to the Kyoto Protocol five years later (1997) which was the first time that agreement was reached to actively work towards reducing GHG emissions. However, the complex and international nature of the aviation and shipping industries resulted in these two industries being excluded from the measures taken in the Kyoto Protocol. Simultaneously, the International Maritime Organization (IMO) had been considering environmental issues through its Marine Environment Protection Committee (MEPC) even though the industry was not yet required to take any formal action. Most recently, increasing pressure to take action has been placed on the IMO by the European Union (EU). The EU has indicated that if the IMO does not continue to demonstrate its progress and implement a system in the near future, the EU tentatively intends to take action between about 2012 and 2015.

The study has investigated a number of cap and trade systems in use for other industries. These trade systems place an absolute upper bound on the level of emissions which is considered to constitute a sustainable operating environment. The total emissions are then allotted, in smaller units (usually one credit equivalent to one ton of CO₂), amongst the emitters in the system. Participants whose emissions exceed their credits must turn to the market, on which carbon credits are sold, in order to acquire additional credits. Conversely, participants who emit less than their allotted credits can sell their additional credits on the market. The EU Emissions Trading Scheme (ETS) is the largest multi-national example of such a system. It currently governs the emissions from about 11,000-12,000 land-based emitting sources.

The study also considers two notable efforts within the shipping industry: the Port of Long Beach/Los Angeles Green Flag Program and the Swedish Maritime Administration's (SMA) Environmentally-Differentiated Fairway Dues system. The Green Flag Program is a voluntary speed reduction program in which the port offers reduced dockage rates to carriers who achieve a certain level of compliance within a defined zone surrounding the port. The program was also expanded to include a fuel subsidy program to promote the use of low-sulfur fuel in the waters surrounding the port. The SMA environmentally-differentiated dues systems is a two part fee structure which assesses an additional fee if fuel with too high a sulfur content is used, while a reduction in fee is also possible for ships whose NO_x emissions are within a predefined range. Both of these systems have proven successful and have experienced optimistically-high participation levels within the portion of the shipping community that they have affected, however; on a fundamental level, these types of systems are not easily scalable beyond the localized capabilities which they have demonstrated.

Different Approaches

The study considered the current input and discussions within the IMO and MEPC and identified three major thought patterns in proposed systems for the maritime industry: (1) an ETS for the shipping industry, (2) CO₂ indexing, and (3) alternative approaches. An ETS for the shipping industry would follow the same fundamental structure as summarized previously, but

would be subject to a number of industry-specific developmental hurdles. Also, while no system has been decided upon, the supporters of an ETS are leaning towards a closed system (at least initially) in which the industry interacts only amongst itself. This simplifies some of the logistical issues, but does not allow ship owners and operators to take full advantage of the inherent efficiency of cargo movement by ship relative to other transportation modes. CO₂ indexing has developed simultaneously alongside the debate between ETS and alternative approaches. The index quantifies emissions levels on a per ship basis by considering a vessel's CO₂ emissions per transport work. This can be done using design parameters (Energy Efficiency Design Index - EEDI) or actual operating conditions (Energy Efficiency Operational Index – EEOI). The IMO has now issued trial guidelines for the design index, and they are currently working to refine the operational index calculation. The most significant alternative approach is to place a levy on fuel bunkers. Other alternative approaches could involve hybrid systems using any combination of the other systems mentioned. The levy on fuel is most heavily backed by ship owners who justify the system due to its easier implementation and because the revenue generated could be reinvested in research and development of new technologies. Currently, there is no consensus on which type of system to use.

Unresolved Issues

A number of conceptual unresolved issues as well as a few critical tradeoffs have been identified and discussed in this study. Regardless of the type of system that is selected, it will require dynamic re-evaluation throughout the development process to ensure that the end result is a meaningful system rather than a merely politically accepted program. The actual objective of real reduction in CO₂ should not be forfeited to a system which looks good on paper and is politically satisfying. A significant concern for this is the notion of common, but differentiated responsibility that is being requested (or demanded) by developing countries. As these countries represent more than 2/3 of the existing world fleet, it is difficult to envision a useful system without their participation. Generally speaking, any of the proposed systems come coupled with significant infrastructure demands ranging from administration to

establishing and maintaining a market to the potential installation of new monitoring equipment aboard vessels. These requirements translate directly into increased cost to owners and operators. Before lunging into this vague domain of new infrastructure and increased expenses, more thorough consideration should be given to the role which ship air emissions plays in the larger context of a solution for global greenhouse gas emissions. While efforts in the shipping industry have produced much valuable information, there has been a lack in contemplation of how a system for shipping can integrate and/or interface with a world-wide solution to pollution from all types of emitting sources. In fact, some systems under current consideration may hinder such a global solution.

Some of the tradeoffs which must be reconsidered throughout the design of a system include: the interdependence and relationship between regulating NO_x/SO_x emissions and CO₂ emissions, the balance between burning higher-grade fuel and increased effort in land-based refineries, lifecycle considerations including building and scrapping of the vessel as well as slowing down ships to reduce emissions and the associated potential need for more ships to maintain trade patterns, and the modal share of cargo movement.

Conclusions and Recommendations

In conclusion, the concept of emissions reduction within the maritime industry has been well received by the community, but existing efforts are fundamentally not capable of resolving the issue with ship air emission within a global solution. Particularly under the pressure of the EU, it is critical that the IMO continue to demonstrate progress on the issue and work towards implementing a system in the near future. This is the only way in which the industry will maintain control of this issue. On that note, the IMO has recently issued trial guidelines for the Energy Efficiency Design Index (EEDI) and is currently working towards refining the Energy Efficiency Operational Index (EEOI). Developing a system capable of real reduction in emissions is one of the most critical issues (especially as a long-term concern) that will require continuous attention and reconsideration. While the type of system has not yet been agreed upon, it is safe to say that developing countries will need to be included in some capacity to make the

system meaningful. Furthermore, ship emissions issues must be considered within the broader context of a global solution to pollution (with all the tradeoffs that are involved).

One evident, but crucial recommendation is to remain active in the development process. For owners and operators, it will ease the learning curve and help management to keep up with current issues (such as those in this study), participate in trial guidelines, and keep up with technology, but brace for new regulation and increased operating expenses. While it is not yet possible to predict the actual increase in cost, it is reasonable to assume that the magnitude of cost will scale proportionately with the size of one's fleet and the age of the vessels and equipment. One interesting consideration for operators is to speculate how a new system will create or change the opportunities both internal and external to their fleets. How can emissions management be addressed cooperatively within a fleet? How might this change the interaction amongst carriers and between other companies in the industry? These types of considerations and recommendations for ship operators have been itemized in Table 1, shown below.

Table 1: Recommended Actions for Ship Operators

Preemptive Measures Towards Emissions Management
<ul style="list-style-type: none"> • Keep management team familiar with current developments (and up to date on background info)
<ul style="list-style-type: none"> • Observe how market-based CO₂ reduction tools have affected other industries (continue to monitor aviation industry)
<ul style="list-style-type: none"> • Participate in trial guidelines both to ease the learning curve and offer critical feedback
<ul style="list-style-type: none"> • Understand where your fleet compares to other ships (check against reported data for trial use)
<ul style="list-style-type: none"> • Upgrade technology where practical, but don't assume that this will result in exemption (even for developing countries)
<ul style="list-style-type: none"> • Brace for some degree of increased operational costs as well as management costs (particularly for large fleets and/or fleets with older vessels and engines)
<ul style="list-style-type: none"> • Consider opportunities that exist (such as trading credits) both internal to fleet or externally and how these interactions may be affected by final regulations

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Definitions and Nomenclature

1. BSA – Burden Sharing Agreement
2. CCA – Climate Change Agreement
3. CER – Certified Emissions Reduction
4. CFR – Code of Federal Regulations (United States)
5. CO₂ – Carbon Dioxide
6. DP – Direct Participant
7. EAU – European Union Allowance
8. EEDI – Energy Efficiency Design Index
9. EEOI – Energy Efficiency Operational Index
10. EPA – Environmental Protection Agency
11. ERU – Emissions Reductions Unit
12. ETS – Emissions Trading Scheme
13. EU – European Union
14. EU15 – Members of the EU prior to the enlargement on 05/01/2004
15. GHG – Greenhouse Gas
16. GT – Gross Tonnage
17. ICAO – International Civil Aviation Organization
18. IMO – International Maritime Organization
19. kg – kilogram
20. kWhr – kilowatt*hour
21. MARPOL – The International Convention for the Prevention of Pollution from Ships
22. MEPC – Marine Environment Protection Committee
23. MGO – Marine Gas Oil
24. mmbTU – Million British Thermal Units
25. NAP – National Allocation Plan
26. NO_x – Nitrogen Oxides
27. RECLAIM – Regional Clean Air Incentives Market
28. RGGI – Regional Greenhouse Gas Initiative
29. RO – Regional Organization
30. SEK – Swedish Krona
31. SO_x – Sulfur Oxides
32. UK ETS – United Kingdom Emissions Trading Scheme
33. UNFCCC – United Nations Framework Convention on Climate Change

1.0 Chapter 1: Introduction and Objective

1.1 Background Information for Greenhouse Gas Reduction Movement

While the terminology 'greenhouse gas reduction' is frequently used, many if not all existing efforts focus primarily on carbon dioxide (CO₂) emissions. This is because CO₂ emissions have experienced the most rapid growth rate of all of the greenhouses gases. CO₂ is also the most significant contributor to the greenhouse effect out of all of the gases with the exclusion of water vapor. Water vapor, however, is naturally-occurring and its abundance is essentially unaffected by human activity on a global scale. Whether referring generally to greenhouse gas emissions or explicitly to CO₂ emissions, this report places emphasis on the reduction of CO₂ emissions. It is estimated that global CO₂ concentration in atmosphere must be held to about 550 parts per million to avoid harmful climate change. In perspective with current data, this creates the need to reduce current levels of emissions by as much as 80%. This issue has long been under consideration on a global level. In 1988 the Intergovernmental Panel on Climate Change (IPCC) created the foundation for the work done at the United Nations Framework Convention for Climate Change (UNFCCC) in 1992. The UNFCCC work led to the Kyoto Protocol in 1997 which called for signatories to actively begin reducing CO₂ emissions levels, but excluded businesses of international nature, namely the shipping and aviation industries. While the shipping industry has not yet been included, the IMO has been concerned with related issues even before the Kyoto Protocol and recognizes the importance of controlling the emissions contribution from shipping.

Currently there are no mandatory measures for greenhouse gas (GHG) reduction that apply directly to the shipping industry. However, the International Maritime Organization (IMO) has been considering this issue for some time and anticipates adopting shipping-specific policy in the near future. Further, the IMO plans to implement a framework for GHG emissions reductions prior to the expiration of the Kyoto Protocol's first commitment period in 2011. In April of 2008, the IMO Marine Environment Protection Committee (MEPC) held its 57th session which adopted guidelines for the reduction of GHG emissions in the shipping industry. From this meeting emerged a set of guidelines for calculating a CO₂ index for use in trials based on vessel design parameters. Further, in June of 2008, the IMO Greenhouse Gas Working Group met to review and expand on the guidelines from the 57th meeting. Most recently, the MEPC held its 58th session in October of 2008. A significant consideration for this meeting was whether GHG emissions reductions for ships should be integrated into existing regulations or whether there was a need for an entirely new system. Also, this meeting served to address any other issues that must be addressed prior to the July 2009 where the MEPC plans to adopt some framework for the reduction of GHG emissions. One key issue is to whom the new GHG regulations will apply.

1.2 Definition of Market-Based Systems

On the most fundamental level, a market-based system is one which implements economic incentives to prompt reduction in air emissions. A number of different market-based systems have emerged in other industries and some examples are currently in trial use in the shipping industry. The options with the ability to control ship air emissions on a global scale

include an international cap and trade program, a levy on fuel, a baseline and credit system, or a simple fine structure for exceeding a predetermined target level.

1.3 Methodology for Feasibility and Suitability Evaluation

Considering the timeliness of this issue and the momentum of the push towards certain action in the near future, this study has taken an objective and practical approach towards assessing the advantages, disadvantages, and potential issues inherent to each system. First, in order to establish how a market-based system can be used to reduce air emissions, an examination was conducted of market-based systems that are currently in place to regulate emissions for land-based industries. Also, there is current activity towards incorporating the aviation industry into a regional and eventually global emissions trading scheme. This work being done in the aviation industry has been considered separately from land-based industry because it more closely parallels the shipping industry due to its international operations. Next, existing and proposed systems were considered for the shipping industry. By considering the underlying concepts behind existing systems of limited scope, it will be determined whether or not similar systems could be scalable to include the international shipping fleet. Proposed systems will then be included into a comprehensive list of possible approaches. Once a list of possible approaches is developed, each approach will be dissected to assess its feasibility and practicality for the shipping industry. From this process, a list will be made of unresolved issues requiring further attention to develop a system for shipping. Finally, based on the entire evaluation and the unresolved issues, a recommended course of action will be suggested.

2.0 Chapter 2: Evaluation of Market-Based Systems Applied to Other Industries

2.1 Overview

This section considers a number of market-based systems that are in existence, or have been used, to control and ultimately reduce CO₂ emissions. Most of the schemes that have been implemented have taken the form of an emissions trading system. The specifications of allocation, auctioning of allowances, and trading between companies and/or sectors vary for each system. This is detailed in the subsequent sections. Additionally, comments on the success of each system have been offered where possible.

2.2 European Union Emissions Trading Scheme (EU ETS)

2.2.1 Overview

The European Union has had an emissions trading scheme in place for CO₂ emissions since January of 2005. Relative to other existing systems, the EU ETS is the largest accounting for upwards of 11,500 emitting sources [39]. The total value of the carbon permits comprising this market is currently estimated to be approximately \$41 billion. The intention with such a trading system is that companies that can reduce emissions levels at a cost less than that of CO₂ credits will make physical reductions whereas companies who find it more affordable to purchase credits will opt to do so. While collectively satisfying the cap on overall emissions, the objective of this program is to meet reduction standards at the lowest possible cost to society [5].

2.2.2 Allocation of European Union Allowances (EAUs)

The EU ETS operates as a carbon market by allotting and trading European Union Allowances or EAUs. The allocation process can be understood in terms of three distinct levels of involvement. The European Commission is the highest level of authority that monitors this system. Each member state, or country, is responsible for deriving its emissions cap and allocation plan known as a National Allocation Plan (NAP). This plan specifies the total amount of emissions permitted and designates each installation's (or company's) share of that total. The European Commission is responsible for approving each member state's NAP on the criteria that it is in compliance with the Kyoto Protocol standards and European Burden Sharing Agreement (BSA) standards. This requirement is defined by the EU as the "Business as Usual" or BAU standard.

Beyond approving each member state's plan, the European Commission had no part in the designation of allowances to each individual installation. Instead, this was the key role played by each member state government usually by the environment ministry and/or the economics/trade ministry.

The EU ETS Directive further specified that each member state could auction up to 5% of their allowances during the first auction period, up to 10% during the second auction period, and then an unlimited amount thereafter. A total of four participating member state governments chose to auction allowances during the first period. This means that all other governments practiced free allocation.

Given the nature of achieving a reduction in emissions levels, it is implied that the NAPs submitted must allot less allowances than the total number needed by all industries. Furthermore, the majority of the EU15 countries specified that the burden of this shortage would be placed on the electricity industry [39]. The primary reason behind this decision was that this industry does not have to stand up against foreign competition. Thus, electricity companies would more easily be able to pass the cost of additional allowances on to the customer without worry of losing business to foreign competitors. Additionally, this system also includes a designated fraction of allowances to be given to new installations free of charge and also voids allowances of companies that shut down. The intent of these policies is 1) not to hinder the ability to start new companies and 2) to avoid strategic relocation of existing companies.

2.2.3 Benchmarking

Benchmarking is an allocation technique used to avoid differing allotment of credits to members of similar nature who have historically produced different emissions levels. Instead, benchmarking allocates based on a comparative index of capacity derived from past performance. Thus, two companies with a similar history of operation would be treated equally based on a standard rate of emissions correlating to their index.

2.2.4 Share-Based Allocation

For the most part, the member states have chosen to allocate credits based on member share of overall emissions levels rather than benchmarking. The methodology behind this type of allotment is that conditions experienced by individual companies, even within a single

industry sector, are much too variable to be generalized by a benchmarking process. In most cases the availability of sufficient historical data and tight time frames further complicated the development of reasonable benchmarks. Thus, most member state governments chose share-based allocation because it was the most agreed upon and easiest method to implement.

2.2.5 Challenges Faced

Among the challenges faced while launching this system was the availability of emissions historical emissions data and the collection of emissions data. Because there was no existing authority in place to keep track of emissions, data collection was forced to be a voluntary process. Additionally, the resulting pool of initial data rendered some methods of allocation infeasible (due to the amount of data available, number of years worth of available data, etc.). For this reason, it is critical that subsequent programs consider the availability of data early on during the developmental stages.

2.2.6 Effectiveness of the System

The system as described in the previous sections has successfully implemented a market which sets a price for excessive CO₂ emissions. It is too early to observe many impacts of this system on trade pattern and international economics. One concern that must be monitored over time is whether abatement will grow to hinder the success of this program.

2.3 Regional Greenhouse Gas Initiative (RGGI)

2.3.1 Overview

The Regional Greenhouse Gas Initiative, or RGGI, is a CO₂ cap and trade program that regulates emissions from power plants (electricity generation) in ten Northeastern states.

Participating states include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The system is designed to reduce emissions levels by ten percent in the participating states by 2018. The reduction is planned to be gradual throughout the duration of the objective timeline. RGGI is the first mandatory carbon market established and implemented in the United States.

2.3.2 Structure of the System

RGGI is designed so that each participant state manages its own trading program under the guidance of the RGGI Model Rule. However, individual companies regulated under RGGI are able to interact with any of the ten state markets in order to acquire allowances necessary to satisfy their state-to-state obligations. Collectively the system places a definite bound on emissions for the entire region comprised by all participant states. Additionally, RGGI does incorporate the use of offsets to satisfy emissions budgets. This means that projects outside of the power industry may be eligible to satisfy some equivalence in CO₂ allowances.

Under this system, operators are required to monitor and record their emissions levels in accordance with the requirements detailed in 40 CFR part 75 [23]. This means that each operator is responsible for installing, certifying, and continuously operating equipment to record maximum CO₂ concentration, emissions rate, gas moisture content, fuel flow rate and all other measurements specified in CFR. The particular type of equipment needed to do this is also detailed in 40 CFR, part 75.

A 'Regional Organization' (RO) was created, in the form of a non-profit incorporation in the state of NY, to manage system administration. It is critical to monitor this system

continuously, especially at startup, as there are concerns that customers within RGGI territory will begin to import electricity supply. Thus, administration will report annually on the level of imported electricity supply. Subsequently, a more elaborate report is to be delivered in 2012. This report will consider the success of the program, impact of the system on electricity pricing and reliability of supply, future reduction targets, imported supply, and evaluation of the use of offsets.

2.3.3 Allocation and Trading

The Model Rule for RGGI, mentioned above, was issued by the participant states on the 15th of August 2006 with the system scheduled to commence on the 1st of January 2009. In the documentation, a regional emissions cap was set. A portion of this cap was then assigned to each state. The distribution of allowances to individual companies is left at the discretion of each state. It is also important to note that banking of allowances is permissible in this system. Proceeds generated through RGGI's allowance auctions are used to support the development of alternative reduced-carbon technologies.

Each company participating in this system must have a single designated account representative to manage its CO₂ budget. In order to hold this position, the individual must apply for a permit through the appropriate regulatory agency in his/her state. As a general guideline for allocation, at least 25% of each state's budget must be put towards 'consumer benefit or strategic energy purpose'. As outlined in the RGGI Memorandum of Understanding, "Consumer benefit or strategic energy purposes include the use of the allowances to promote energy efficiency, to directly mitigate electricity ratepayer impacts, to promote renewable or

non-carbon-emitting energy technologies, to stimulate or reward investment in the development of innovative carbon emissions abatement technologies with significant carbon reduction potential, and/or to fund administration of this program,” [25]. As mentioned above, the remainder of allowances is distributed at the discretion of each state. However, almost all of the states involved have declared that they intend to auction all of their allowances to support consumer benefits and the overall impact of RGGI on electricity rates.

Initially, RGGI declared that approved offset projects included: landfill methane capture and combustion, sulfur hexafluoride capture and recycling, sequestration of carbon due to afforestation, end-use efficiency for natural gas, propane and heating oil, avoided methane emissions from agricultural manure management operations, and projects to reduce fugitive methane emissions from natural gas transmission and distribution [25]. There is an application process which requires a project sponsor and independent party verification in order to properly acquire allowance credit from offset projects. Where applicable offset projects must implement gas collection systems to monitor gas flow rates. These data are then used to calculate the actual level of emissions reduction as specified in the RGGI Model Rule.

A study was conducted in order to develop a feasible auction plan. This study concluded with a list of 16 recommendations for RGGI auction format. The key recommended features are summarized below while the entire list can be found in reference [41]. Auctions are to be held quarterly and will take on a uniform-price format. A reserve price will be set and made public. Unsold allowances may either be put into a contingency reserve account to reduce fluctuation in pricing or may simply be carried over into the next auction. Lastly, auction

information will be made public, and auctions will continuously be reviewed and evaluated by administration.

2.3.4 Effectiveness of the System

Because RGGI has only held one allowance auction and first becomes effective on January 1st 2009, it is not yet possible to evaluate the performance of the overall system. However, it can be noted that the system successfully placed a cap on emissions within the electricity sector in each of the ten participating states. The infrastructure is in place and a market for trading CO₂ allowances has been established making it the first of its kind in the United States. While it will not be certain until the annual reports begin to be issued, it has been estimated that RGGI will cause a \$3-\$16 annual increase in average household electricity bills [25].

2.4 United Kingdom Emissions Trading Scheme (UK ETS)

2.4.1 Overview

The United Kingdom Emissions Trading Scheme (UK ETS) was initiated by the United Kingdom Department for Environment Food and Rural Affairs in April of 2002. This system, however, was designed to end (and did end) in December 2006. The UK ETS included members referred to under the system as “Direct Participants” or DPs. All of the DPs were volunteers into the system with the objective of reducing their historical emissions levels. As stated in an Enviro Consulting report (commissioned by Defra) the system was started with three core objectives in mind:

- 1) To secure cost-effective GHG emissions reductions;

- 2) To give the UK companies early experience of emissions trading, with a particular view to being ready for the European Union Emissions Trading Scheme;
- 3) To encourage the establishment of an emissions trading centre in London.

2.4.2 Structure of the System

Though participation in the program was voluntary, all participants were eligible to gain a portion of £215 million incentive that was offered. Also, in order to properly interpret data from the UK ETS, one must understand that organizations belonging to a Climate Change Agreement (CCA) were also eligible to participate in this system. In this circumstance, the company could buy supplemental allowances if it did not meet its CCA Agreement.

2.4.3 Allocation and Trading

On the most basic level, DPs were allocated allowances on a cap and trade basis and other participants were allocated allowances using a baseline and credit approach. The distinction is that DPs are allotted allowances in advance for their annual (predetermined) cap whereas others are given allowances at the end of each period corresponding to their recorded emissions levels compared to their target levels. Also, there were two types of 'targets' used in this system. An absolute target is a predetermined CO₂ emissions maximum used for DPs. A relative target, used mostly for other participants, is valued in emissions per unit of output. The importance of this distinction is that those with relative targets may only trade on a baseline and credit basis.

As far as transaction, there were defined transfers of allowances and trading of allowances. An allowance transfer simply means that some quantity of allowances were moved

between different accounts whereas as a trade, by definition, involves a transfer in conjunction with a financial transaction. Trades were permissible between DPs directly or through 'emissions brokers'. It is also important to note that trades were conducted assuming seller liability. This means that the seller is responsible for assuring that the trade will not inhibit them from meeting their emissions quota. The seller is otherwise subject to penalty. The primary reason for this approach is to discourage excessive over-selling. The banking of allowances was permitted as it motivates participants to be proactive in their emissions reductions strategies. Also, allowances purchased are considered for tax relief while profits from allowances sold are subject to taxes.

In addition to the allocated allowances, certain projects conducted in the UK are eligible to earn credits. All projects must be preapproved by the government. In general, the government considers mostly projects in electricity generation. This includes improving the efficiency of existing operations and/or new projects in environmentally-friendly energy generation. Because the focus of this program is reduced emissions, sequestration programs are not as easily substituted for credits.

Each company participating in this system was responsible for calculating their own emissions. Interestingly for this system, imported energy was included as emissions while exported energy was not. The documentation for this system gives conversion factors based on the source of the energy in (kg CO₂/ kWhr). Each participant is required to report its emissions on an annual basis.

Lastly, the incentive money offered was auctioned using a 'descending clock'-type auction. Basically, a price was announced per ton of CO₂. Each party then bid a reduction in emissions in tons of CO₂. This process was repeated as necessary until the price multiplied by the sum of all bids was within the budgeted incentive money. At this point, the money was distributed proportionally according to each party's bid.

2.4.4 Effectiveness of the System

The companies who volunteered to partake in this system were surveyed to determine their motivation for participation. The primary reasons, as collected by the Enviro Report, were:

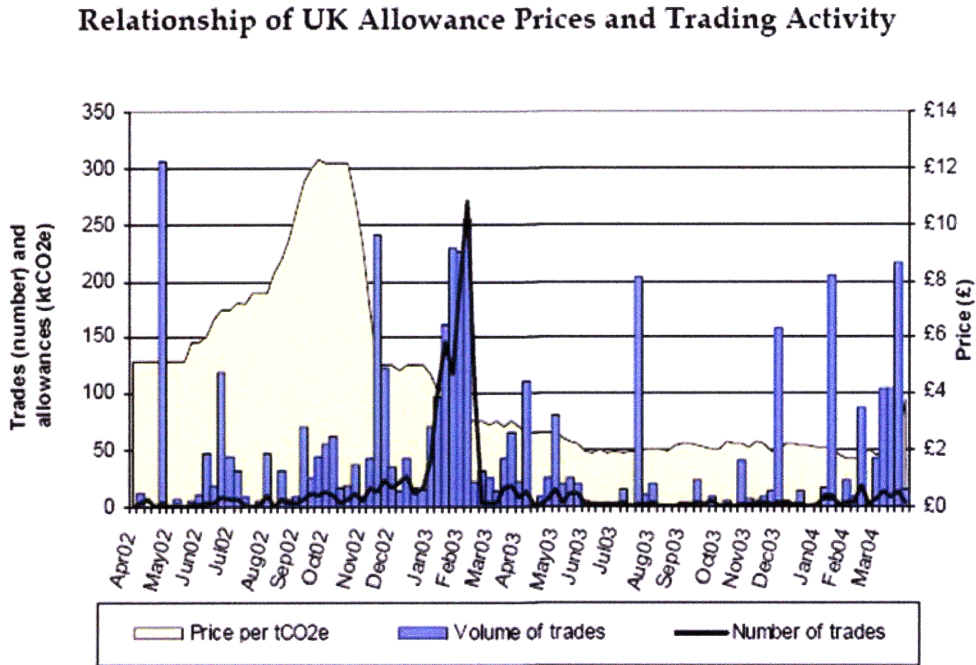
- 1) Energy savings and/or emissions reductions.
- 2) Business opportunity from incentive offered and/or from 'commercially beneficial impacts'.
- 3) Preparatory measure for EU ETS.
- 4) General experience in emissions trading.

During the first couple of years in this system, 946 companies participated in trading, and individual transactions ranged from 1-220,000 allowances [1]. This corresponds to 2.8 million tons of CO₂ allowances traded in the first year of operation and 1.7 million tons of CO₂ allowances traded during the second year.

In terms of emissions reductions accomplishments, 22 DPs recorded levels lower than targeted during the first year. However, 95% of emissions under target were accomplished by only 8 DPs. Overall, this resulted in a reduction of 4.6 million tons of CO₂ during the first year.

A report produced by Nera Consulting to evaluate the UK ETS includes the graph shown in Figure 1: UK Allowance Prices and Trading Activity (NERA Report).

Figure 1: UK Allowance Prices and Trading Activity (NERA Report)



The majority of companies involved in this system were said to have at least broken even. However, many companies noted that there were significant learning costs suffered while learning compliance in an emissions trading system. On a positive note, many reported that in general, participation in this system consequently improved the efficiency of their operations in terms of environmental management.

2.5 Regional Clean Air Incentives Market (RECLAIM)

2.5.1 Overview

Regional Clean Air Incentives Market, or RECLAIM, is an emissions trading program in California that was started in 1994. RECLAIM is a cap and trade program for nitrogen oxides (NOx) and sulfur oxides (Sox) aimed which had the initial objective to cut back on NOx emissions by approximately 70% from 1994-2003. This program is supported by the South Coast Air Quality Management District and includes more than 300 participants in the NOx program and 33 participants in the SOx program.

2.5.2 Structure of the System

RECLAIM was designed to include stationary sources of NOx and/or SOx emissions that had emitted 4 tons of NOx or SOx in 1990 or later. In order to make emissions monitoring and recordkeeping more feasible and practical, multiple tiers were developed to characterize equipment based on their capacity. Then different standards of monitoring and recordkeeping were designated for each tier. For instance, in the case of 'large sources' for NOx emissions (sources with equipment capacity as defined in the documentation: for instance combustion equipment with annual heat input between 10-40 mmBTU) are required to use fuel meter or continuous monitoring systems and submit monthly electronic reports. Note that this methodology is not directly analogous or transferable to CO₂ emissions. A unique design feature in the monitoring requirements was the incorporation of missing data provisions as a way of using alternative means (other than continuous emissions monitoring systems) to report emissions. However, missing data provisions used very strict, worst-case assumptions. So, this

created a buffer time for companies to get on track with required recordkeeping methods, but provided incentive to make the transition as quickly as possible. This trend is evidenced in the proportions of emissions reported using missing data provisions for the first 10 years. These data are shown below in Figure 2: Percentage of Reported Emissions Using Missing Data Provisions.

Figure 2: Percentage of Reported Emissions Using Missing Data Provisions

Percentage of Reported Emissions Using Missing Data Provisions

	Percent of Reported Emissions Using Substitute Data										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
NO _x	23%	20%	18%	7.3%	9.6%	6.5%	8.1%	3.4%	4.5%	8.3%	3.0%
SO _x	40%	16%	16%	13%	20%	10.7%	11%	4.8%	4.7%	10.4%	3.6%

2.5.3 Allocation and Trading

RECLAIM was designed to implement a two-cycle system in which half of the participants were divided into two groups who operated on an annual allocation plan that was staggered by six months between the groups. The reason for this was to make the market less susceptible to excess or shortage.

2.5.4 Effectiveness of the System

The United States’ Environmental Protection Agency (EPA) conducted an evaluation of the RECLAIM system. The evaluation was based on a number of interviews held with stakeholders, companies in the program, environmental and regulatory agencies, and allowance brokerage companies. In their evaluation report, they concluded with the following, “Lessons Learned from Reclaim’s Experience” [4]:

- “Market-based programs require significant planning, preparation, and management during the development throughout the life of the program.
- Market information is a key factor affecting facility decision-making.
- Regulations should strive to create confidence and trust in the market by making full commitment to the program and ensuring consistency in the market and their policies.
- Unforeseen external circumstances (like energy deregulation) can have dramatic impacts on market-based programs. Therefore, these programs must be designed to react quickly and effectively to unforeseen external factors.
- Periodic evaluation, revisiting of program design assumptions, and contingency strategies are crucial to keeping programs on track.
- Regulators need to have a strong understanding of the regulated facilities and the factors impacting their decision-making.”

3.0 Chapter 3: Aviation and the EU ETS

3.1 Overview

Currently, the aviation industry in Europe is not covered by the EU ETS, however, there is proposed legislation to regulate aviation emissions within the EU by 2011 and to regulate emissions from all flights using EU airports by 2012. The intention of this program is to gently merge it into the EU ETS as a model for other countries to become included into a worldwide emissions trading scheme. The Commission of the European Communities establishes the framework for this system in their 2006 proposal for amendment to Directive 2003/87/EC (*Establishing A Scheme for Greenhouse Gas Emission Allowance Trading Within the Community and Amending Council Directive 96/61/EC, 13 October 2003*) which established the initial greenhouse gas emissions allowance trading scheme. With a said growth in international aviation emissions of more than 87% since 1990, it is estimated that aviation emissions could negate more than 25% of environmental benefits accomplished (for the EU) under the Kyoto Protocol [20].

3.2 Structure of the System

In 2004, the members of the International Civil Aviation Organization (ICAO) agreed that an aviation-specific trading scheme was not desirable. Thus, the EU directive proposes incorporation of international aviation emissions into member States' trading schemes. Note that this proposal was written by the European Union not the ICAO. While the members of the ICAO agreed that this approach was conceptually appropriate, there is much controversy

amongst actual air carriers as to when and how new measures should be implemented. The key aspects of this system are explicitly listed in the directive as follows:

- “Aircraft operators will be the entities responsible for complying with the obligations imposed by the scheme.
- The scheme will cover all flights arriving at or departing from an airport in the Community (EU) as of 1 January 2012. Flights between EU airports will be covered from 1 January 2011.
- Flights by State aircraft, flights under visual flight rules, circular flights, flights for testing navigation equipment or for training purposes, rescue flights and flights by aircraft with a maximum take-off weight of less than 5700 kg will be excluded from the scheme.
- To address other gases, by the end of 2008, the Commission will put forward a proposal to address the nitrogen oxide emissions from aviation after a thorough impact assessment.
- In order to avoid duplication and an excessive administrative burden on aircraft operators, each aircraft operator, including operators from third countries, will be administered by one Member State only.
- In contrast to the existing scheme, the method of allocating allowances will be harmonized across the Community (EU).

- The total number of allowances to be allocated to the aviation sector will be determined at Community level by reference to average emissions from aviation in the years 2004-2006.
- A fixed percentage of the total quantity of allowances will be allocated free of charge on the basis of a benchmark to aircraft operators which submit an application (the earliest application relating to 2008 data.) For the period 2011-2012 this percentage will correspond to the average percentage proposed by the Member States including auctioning in their national allocation plans. Thereafter, this will be reviewed in the light of the results of the general review of the emissions trading scheme.
- The details of how auctioning will work such as appropriate design and timing will be set out in a Commission Regulation. Auctioning proceeds should be used to mitigate and adapt to the impacts of climate change and to cover administrative costs.
- Like other participants in the Community scheme, aircraft operators will have to monitor their emissions of carbon dioxide and report them to the competent authority of its administering Member State by 31 March each year. The reports must be verified to make sure that they are accurate. The basic principles for monitoring, reporting and verifying emissions set out in the proposal will be elaborated by guidelines.

- Aircraft operators will be able to buy allowances from other sectors in the Community scheme for use to cover their emissions.
- Aircraft operators will also be able to use project credits – so-called Emissions Reductions Units (ERUs) and Certified Emissions Reductions (CERs) – from the Joint Implementation or Clean Development Mechanism (JI/CDM) up to a harmonized limit equivalent to the average of the limits prescribed by Member States in their national allocation plans for other sectors in the Community scheme.
- Domestic aviation will be included in the scheme and treated in the same way as international aviation.
- Special considerations to the treatment of air services to remote or isolated regions which are particularly dependent on air transport services, can best be given within the framework of existing measures such as public services obligations and aid having a social character under Article 87(2) of the Treaty.”

The above-stated objectives set forth for the directive were to be funded entirely by the ‘financial instrument for the environment (LIFE+ for 2007-2013)’.

Under the proposed system, 100% of allowances (as determined from historical data) are to be allotted. Each aircraft operator is responsible for monitoring and reporting its emissions. This must be done in compliance with the directive by recording fuel consumption and multiplying by a given emissions factor.

3.3 Allocation and Trading

Under this system, each aircraft operator must apply directly to their governing member state for allowance allocation. In general terms, this is done by providing verified 'tonne-kilometer' data. Beyond this part of the process, the operator is given EUAs which may be used in the EU ETS in the full capacity described in Section 2.2.

3.4 Conclusions

Because international flights comprise a significant percentage of aviation in the EU and are not included in the Kyoto Protocol's targeted reductions, a special approach has been taken to control these emissions. The responsibility for developing a system to regulate international aviation emissions has been placed within the ICAO as they are the world-wide authority for aviation. It is most important to note that the aviation industry gave preference to joining the EU ETS as opposed to creating their own emissions trading system to account for international emissions. After thorough consideration, stakeholders, the ICAO, and the European Commission have agreed that integrating international aviation emissions into the EU ETS is most reasonable approach. When compared against other options such as a levy on fuel this option has the lowest cost to society and therefore produces the desired economic benefits with the least impact on the international aviation commercial market. While this approach does not directly affect ticket prices, airlines will incur additional expenses associated with reducing emissions or purchasing additional allowances. Thus, it has been speculated that some cost on the order of €1.8-€9 for flights within the EU will be passed on to the customer through ticket pricing. It is also predicted that this increase in ticket price will grow larger for

international flights in proportion to flight distance. This implies that the additional expenses incurred by airlines would not be distributed uniformly amongst ticket prices, but rather according to distance traveled. It has also been noted that this predicted increase is much lesser in magnitude than the increases seen recently due to rising oil prices [19].

Another consideration is how the addition of the aviation industry will affect the already existing market for allowances in the EU. It is predicted that this abrupt increase in demand will be absorbed by an increased number of emissions offsetting projects rather than a steep increase in allowance market price.

The governments of the European Union just recently (October 2008) gave final approval to include in the EU ETS by 2012 all flights, including international, with origin or destination in the EU [9]. This news was received with strong opposition from both European carriers and by the United States' aviation industry. An October *New York Times* article stated that, "Airline Chiefs immediately criticized the decision, saying it would cost the industry at least 3.5 billion euros (\$4.4 billion) each year to comply" [9]. Many oppose this regulation saying that its objective will not be realized without the inclusion of worldwide markets. The general reaction appears to be that this step is not yet ready to be taken and that it is poor timing in conjunction with the recent record-high oil prices that have already devastated air carriers. Propositions are being devised to convince the European Union to financially support this transition if they want to persist with this regulatory move during such a low point in the recent economy.

4.0 Chapter 4: Evaluation of Existing Systems Applied to the Shipping Industry

4.1 Overview

While this chapter is not intended to be an exhaustive list of all efforts to reduce emissions in the shipping industry, it examines more closely some existing programs, how they operate, and their effectiveness. The Green Flag Program on the West Coast of the United States and the Swedish Maritime Administration's environmentally-differentiated fairway dues system are two of the most developed examples.

4.2 Port of Long Beach/Port of Los Angeles Green Flag Program

4.2.1 Overview

Both the Port of Long Beach and the Port of Los Angeles, two of America's most highly trafficked ports, have long prided themselves in environmental awareness. In 2006, the South Coast Air Quality Management District, California Air Resources Board, and the United States Environmental Protection Agency (EPA) cooperated to develop the San Pedro Bay Ports Clean Air Action Plan. This is a five-year plan for significant overall emissions reductions from land-based port equipment, trucks in and out of the terminals, and ships utilizing the ports. The Green Flag Program targets the ship air emissions reduction portion of this overall plan.

The Green Flag Program is a multi-million dollar effort funded by the port. The program promotes locally-reduced air emissions by setting a voluntary 12-knot speed limit extending for approximately 20 miles around the port's surrounding waters. Though the speed limit is voluntary, the port rewards compliance with public recognition and reduced dockage rates. In particular, any carrier that achieves at least 90% compliance in one calendar year is granted a

15% discount in dockage fees for the following calendar year. The speed of every vessel within the designated zone is recorded by the Marine Exchange of Southern California [46].

In addition to the voluntary speed reduction program, the ports have also begun a couple of other parallel initiatives. The Port of Long Beach has invested approximately \$10 million dollars in a one-year program to promote the use of low sulfur fuel when operating within 40 nautical miles of the port. The program began on July 1, 2008 and will continue until June 30, 2009. During this time period, the port will pay the cost differential for carriers who opt to burn more expensive low-sulfur MGO with 0.2% sulfur content or less [46]. Also, the port is currently studying the implications, both technical and financial, of adopting a 'cold-ironing' policy. The ports of Long Beach and Los Angeles have already set tentative plans for all major cruise and container terminal berths to be fit with shore power within ten years.

4.2.2 Effectiveness of the System

In general, the Green Flag Program has been successful in achieving the type of local air emissions reduction for which it was developed. The Port of Long Beach's Executive Director, Richard D. Steinke said, "The Green Flag Program has been a hit. It's been well received in the shipping community and has achieved major reductions in air pollution," [46]. During the three years since its installment, overall program compliance has risen to 90% of all visiting vessels. Based on this success, in December of 2008, the Port of Long Beach is expanding the program to include a 25% discount on dockage fees for vessels complying with the 12-knot speed limit within a 40 nautical mile zone surrounding the port. Among the numerous statistics published

on the port's website, the Port of Long Beach said that the Green Flag Program reduced CO₂ emissions from ships by 26,700 tons in 2007 [46].

4.3 Swedish Fairway Dues

4.3.1 Overview

Since 1998, the Swedish Maritime Administration (SMA) has promoted environmental awareness by implementing environmentally-differentiated fairway dues. Swedish fairways have long been funded exclusively by the SMA's fairway dues system. These fees go towards support items such as navigation aids, ice breaking, pilots, etc. The general fee takes on a two-part structure. Part of the fee is assessed based on the vessel's gross tonnage (GT) and the second part is based on the volume of cargo originating or destined for Swedish ports. In 1996, as part of a cooperative effort between the SMA, the Swedish Ship Owners Association, and the Swedish Ports' and Stevedores' Association a plan was agreed upon to reduce ship emissions by 75% over the course of only a few years. As a result of this plan, the environmentally-differentiated fairway dues system was introduced in 1998. This was the primary means of achieving their goal; however, a significant amount of money was also invested in emissions cleaning and treatment. This system has since undergone some minor changes in fee assessment.

Under the new scheme, the GT portion of the fee was eligible for discount based on the sulfur content of the fuel being burned and on the NO_x emissions rate. The newest revision of this system includes an additional charge for vessels not burning low-sulfur fuel and still includes a discount for vessels achieving predetermined reduced NO_x emissions. Table 2 and

Table 3 show the current environmentally-differentiated fee structure (monetary values given in Swedish Krona – SEK).

Table 2: Environmentally-Differentiated Dues: Sulfur Content

Sulphur charges

The Port of Göteborg makes an extra charge of 0.20 SEK/GT for each call.
For passenger ships, passenger ferries or rail ferries, if the sulphur content of the fuel for running the ship exceeds 0.5 per cent by weight.
For other vessels, if the sulphur content of the fuel for running the vessel exceeds 1.0 per cent by weight.

Table 3: Environmentally-Differentiated Dues: NO_x Discount

Nitric oxide discount

Ships that by various measures have reduced their nitric oxide emissions to less than 12 grams per kilowatt-hour are given a reduction of the harbour dues as follows:

Emission level in grams of NO_x/kWh	Reduction in SEK per unit of the ship's gross tonnage (GT)
11.99 - 6.01	0.05 SEK/GT
6.00 - 2.01	0.10 SEK/GT
2.00 or less	0.20 SEK/GT

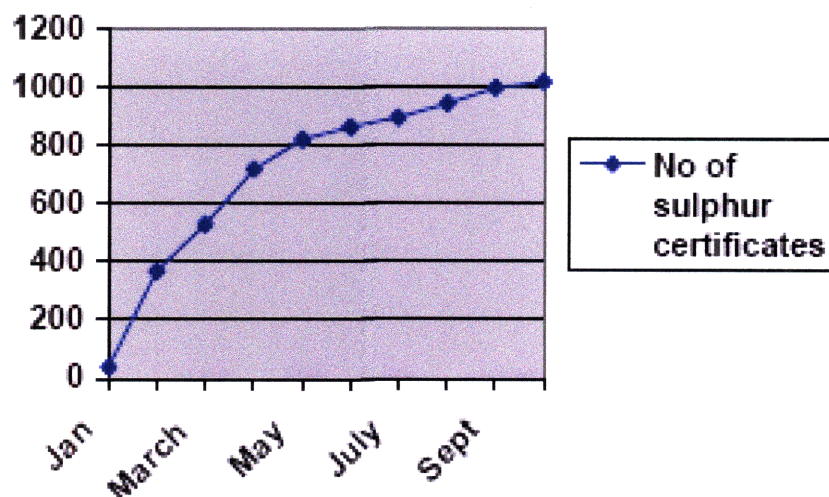
In order to redeem the benefits of the NO_x discount plan, the operator must file an application with the SMA for verification of its reduced NO_x levels. Upon completion of the application process, a certificate is issued stating the vessel's certified NO_x emission level per kWh. Additionally the vessel operator must provide documentation verifying exclusive use of low-sulfur fuel in order to avoid any additional fees.

4.3.2 Effectiveness of the System

An essay written in 2002 by Henrik Swahn, Senior Advisor at the Department for Maritime Policy and Public Affairs at the SMA provided some early quantitative evidence of the

program's success. At the time of the report, 25 major ports had already implemented the environmentally-differentiated dues system. In the 2001 SMA Annual Report it was estimated that the coastal waters of Sweden had seen a decrease on the order of 50,000 tons of SO_x and 27,000 tons of NO_x. Figure 3: Number of Ships Attaining Sulfur Certificates in 1998 illustrates the early success of the low-sulfur incentive program [50]. In 1999 it was estimated that there had been a reduction in sulfur emissions by approximately 30% by volume.

Figure 3: Number of Ships Attaining Sulfur Certificates in 1998



The essay also includes a discussion of optimal maritime emission pricing. The underlying conclusion in this discussion is that the operator should pay a fee equal to the marginal cost of 'damage'. A constant predetermined estimate of the marginal cost of damage is used in this paper. It is important to note that assessing the cost to society is arguably the most difficult challenge in this type of approach. The study recognizes that ships calling frequently in ports practicing this method would realize abatement costs lower than the marginal cost of damage

while ships less frequently calling these ports would have higher abatement costs. This suggests that the only truly effective policy would have to govern worldwide.

4.4 Conclusion

While the significant effort invested in each of these programs is statistically evidenced to achieve decreasing levels in ship emissions, it is most important to realize that these achievements are on a localized level. The scalability of systems like these is an issue that will be investigated more closely in subsequent chapters. A positive similarity to extract from these programs is that the shipping community (at least those involved in these particular cases) has responded well to these incentivized programs. This is a good indication that in the right context and under proper motivation, the shipping industry will take justified steps towards environmentally cooperative operation.

5.0 Chapter 5: Evaluation of Proposed Systems Applied to the Shipping Industry

5.1 Overview

Expedited by external pressure for the shipping industry to develop and implement formal policy for the control of ship air emissions, the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) has been and is continuing to investigate potential emissions regulations mechanisms. Due to the international nature of the shipping industry, working through the IMO is the most appropriate route for developing a solution fit for the entire shipping community. Most recently this issue has been the sole topic of discussion at the June 2008 meeting of the MEPC Working Group on Greenhouse Gas Emissions (organized as a result of the MEPC's 57th meeting) as well as a significant issue of discussion at the MEPC's 58th Session in October 2008. These meetings have opened this issue to comment from any and all IMO members and many IMO Member Governments have participated to make this a collaborative effort. For reference, Table 4 lists Member Governments that were present at the intersessional GHG working group meeting.

Table 4: IMO Member Governments Participating in GHG Working Group

AUSTRALIA	MARSHALL ISLANDS
BAHAMAS	NETHERLANDS
BELGIUM	NEW ZEALAND
BRAZIL	NORWAY
CANADA	PANAMA
CHILE	POLAND
CHINA	PORTUGAL
CYPRUS	REPUBLIC OF KOREA
DENMARK	SAUDI ARABIA
FINLAND	SINGAPORE
FRANCE	SOUTH AFRICA
GERMANY	SPAIN
GREECE	SWEDEN
INDIA	TURKEY
ITALY	UNITED KINGDOM
JAPAN	UNITED STATES
MALTA	

Although the MEPC's work is still evolving, it is possible to recognize three types of approaches being taken. The first major concept under investigation is the feasibility of an emissions trading scheme (ETS) for the shipping industry. The other major development is a technical approach in the form of a design or operational CO₂ index for ships. The last category of proposed ideas, grouped here as alternative approaches, is comprised mostly of bunker levy considerations or concepts which represent a combination of multiple approaches. The subsequent sections of this chapter serve to compile general concepts and issues for each approach gathered from IMO Member Government submittals for the GHG working group and 58th Session. Table 5 and Table 6 show how documents submitted for these two meetings can

be loosely grouped as discussed above. Note that documents with concepts categorized as 'other' are primarily suggestions/amendments to previous works.

Table 5: Document Summary: GHG Working Group June 2008

Summary of Documents Submitted to Agenda for MEPC GHG Working Group June 2008			
Concept	Document	Submitted By:	Description
Market Based	GHG-WG 1/5/7	Germany	Maritime ETS
Market Based	GHG-WG 1/5/6	France	Carbon Market
Market Based	GHG-WG 1/5/5	Norway	ETS
Market Based	GHG-WG 1/5/3	European Commission	ETS
Market Based	GHG-WG 1/5/2	Interferry	maritime ETS
Indexing	GHG-WG 1/2/2	Japan	CO2 index
Combination	GHG-WG 1/5	Friends of Earth International	Mandatory Policies (technical/operational/economic) - Design Index- cold ironing - vessel traffic planning - speed reduction - fuel levy - cap and trade
Combination	GHG-WG 1/5/4	Norway	Levy cap and trade

Table 6: Document Summary: MEPC 58th Session (GHG Issues)

Summary of Documents Submitted to Agenda for MEPC 58th Session			
Concept	Document	Submitted By:	Description
Agenda	MEPC 58/1	Agenda	
Market Based	MEPC 58/4/22	Denmark	Feasibility of International Compensation Fund
Market Based	MEPC 58/4/25	France, Germany, Norway	Comment on GHG-WG meeting (Oslo)
Market Based	MEPC 58/4/19	International Bunker Industry Association	CO2 Cap and trade for shipping sector
Market Based	MEPC 58/4/39	World Wide Fund for Nature (WWF)	Addresses concerns regarding market-based instruments
Indexing	MEPC 58/4/36	Canada	Corrective coefficient calculation for ice-strengthened vessels
Indexing	MEPC 58/4/37	Canada	Relationship between design and operational index
Indexing	MEPC 58/4/38	Canada	Considerations for determining the target reduction for required index
Indexing	MEPC 58/4/33	China	Comments on new ship design CO2 index (annex 5 of MEPC58/4)
Indexing	MEPC 58/4/34	China	Comments on proposed baseline formulation
Indexing	MEPC 58/4/12	Community of European Shipyards' Association (CESA)	Technical comment with recommendation of market-based system to complement indexing
Indexing	MEPC 58/4/18	Cyprus	Mandatory design index, voluntary operational index
Indexing	MEPC	Denmark	Methodology for baseline calculation

	58/4/8		
Indexing	MEPC 58/4/9	Denmark	Verification methods for calculations
Indexing	MEPC 58/4/10	Denmark	Auxiliary power considerations
Indexing	MEPC 58/4/24	Denmark	Considerations for expressing normal max load for auxiliary engines in CO2 index calculation
Indexing	MEPC 58/4/6	Denmark and Norway	Definition of ship speed
Indexing	MEPC 58/4/7	Finland and Sweden	Ship-specific design coefficients - ice-strengthened vessels
Indexing	MEPC 58/4/30	International Association of Classification Societies (IACS)	Comments on GHG-WG meeting (Oslo) with regard to CO2 design index and verification of input parameters
Indexing	MEPC 58/4/14	INTERTANKO	Simplified index suggestion
Indexing	MEPC 58/4/13	INTERTANKO, OCIMF, BIMCO	Methodology for monitoring ship efficiency
Indexing	MEPC 58/4/26	Japan	Incorporating energy-saving device effects into CO2 index calculation
Indexing	MEPC 58/4/27	Japan	Guidelines for obtaining
Indexing	MEPC 58/4/28	Japan	Technical comment with regard to wind drag and added wave resistance considerations for performance coefficient, fw
Indexing	MEPC 58/4/29	Japan	Speed reduction coefficient calculation
Indexing	MEPC 58/4/11	Marshall Islands	Proposed amendments to MEPC/Circ.471 for measure of cargo mass for various ship types
Indexing	MEPC 58/4/3	Note by Secretariat	Outcome of work with UNFCC and IPCC to harmonize C to CO2 conversion factor
Indexing	MEPC 58/4/35	United States	Proposed revision to CO2 index calculation as per draft guidelines

Combination	MEPC 58/INF 21	Friends of the Earth International (FOEI)	Technical/operational measures for reduction of GHG emissions
Combination	MEPC 58/4/21	Institute of Marine Engineering Science and Technology (IMarEst)	Framework considerations for Index, port tax, fuel levy, ETS
Combination	MEPC 58/INF 14	Norway	Technical and operational measures
Combination	MEPC 58/4/15	United Kingdom	Suggested framework for shipping sector
Combination	MEPC 58/4/17	United States	Suggested framework for voluntary and mandatory actions
Other	MEPC 58/4/23	Australia	Suggestions for IMO system framework
Other	MEPC 58/4/16	Australia, Canada, Denmark, Germany, Japan, Marshall Islands, Norway, Panama, United States	Proposed amendment to principles set forth in MEPC 57/4/2
Other	MEPC 58/4/31	Brazil	Comments on GHG-WG meeting (Oslo)
Other	MEPC 58/5/4	Denmark, Japan, Korea	MEPC 57 guidelines for Tier III exhaust gas after-treatment systems
Other	MEPC 58/5/3	France and Germany	Proposed revision to MARPOL Annex VI Emission Control Area (ECA) designation criteria
Other	MEPC 58/5/11	INTERFERRY	MARPOL Annex VI - Sulphur limitations
Other	MEPC 58/14	International Parcel Tankers Association (IPTA), International Chamber of Shipping (ICS)	MARPOL Annex VI - regulation 18(2) revision
Other	MEPC 58/5/10	Japan	Suggested change in date of entry for MARPOL Annex VI revisions
Other	MEPC 58/5/8	Marshall Islands, International Chamber of Shipping	Proposed amendment to MEPC.170(57)

Other	MEPC 58/1/1	Note by Secretariat	Annotations and provisional timetable for MEPC 58th Session
Other	MEPC 58/4	Note by Secretariat	Report on the outcome of intersessional meeting of GHG-WG
Other	MEPC 58/4/1	Note by Secretariat	Fuel quality specification
Other	MEPC 58/4/2	Note by Secretariat	Progress report on 2000 IMO GHG Study Update
Other	MEPC 58/4/5	Note by Secretariat	Outcome of 28th meeting of Subsidiary Body for Scientific Technological Advice (SBSTA)
Other	MEPC 58/4/20	Note by Secretariat	Legal consideration in context of Kyoto Protocol
Other	MEPC 58/5	Note by Secretariat	Draft amendments to MARPOL Annex VI and NOx Technical Code
Other	MEPC 58/5/1	Note by Secretariat	Guidelines for VOC Management Plan
Other	MEPC 58/5/2	Note by Secretariat	Summary of interpretations and guidelines under current MARPOL Annex Vi
Other	MEPC 58/5/5	Note by Secretariat	Clarification for advice for guidelines for exhaust gas cleaning systems MEPC.170(57)
Other	MEPC 58/5/6	Oil Companies International Marine Forum (OCIMF)	Review of MEPC 57 ECA criteria
Other	MEPC 58/5/9	United States	Amendments to Annex VI- recommended technical correction to regulation 13(7)(a)/support for regulation 13(7)
Other	MEPC 58/5/12	United States	Support for amendments to MARPOL Annex VI
Other	MEPC 58/4/32	China and India	Comment on GHG-WG meeting (Oslo)
Other	MEPC 58/INF 7	ICS, BIMCO, Intercargo, Intertanko, OCIMF	Ship Efficiency Management Plan
Other	MEPC 58/5/7	International Petroleum Industry Environmental Conservation Association (IPIECA)	Re-visitation of MEPC 57 qualification criteria for emission control areas (ECA)

5.2 ETS for the Shipping Industry

5.2.1 Overview

The foundation for this approach is to hold the shipping industry accountable for its emissions by including shipping in an emissions trading scheme. This can be done either by introducing shipping into a pre-existing system such as the EU ETS (open system – including other industries) or to develop an ETS exclusively for the shipping industry (closed system). As a point of clarification, the notion of ETS in this context is referring particularly to CO₂ emissions. The discussion thus far overwhelmingly suggests that an ETS be organized solely for the shipping community. However, this issue has not been finalized and both open and closed systems are still under consideration.

5.2.2 Potential Effectiveness and Limitations

A positive aspect of an ETS is that a true upper bound for CO₂ emissions can be defined and adhered to. Thus, under the large assumption that the effects of global warming are comprehended well enough to determine necessary levels of reduction for the shipping industry, an ETS would provide an absolute aggregate monitoring mechanism. With all technical and logistical issues aside, an ETS is a sound way to limit overall emissions. Also, establishing a market for CO₂ would stimulate the most cost-effective approach towards reduced emissions.

Of course there are numerous issues and potential limitations that complicate the development of a feasible, practical, and effective ETS. Inevitably governance-related issues with regard to developing countries quickly complicate this plan. A number of member

governments noted that many proposals for a shipping ETS were submitted by European countries. As follow-on to this point, Saudi Arabia suggested that a European shipping ETS would be a good trial to evaluate this plan. While this may not be the best or most practical approach, a key point made is that in developing this scheme, its effectiveness in targeting global emissions must be fully understood. Thus, a smaller scale trial may provide quantitative evidence of such a system's ability to reduce global emissions from ships. Other issues include; how to monitor, record, and verify emissions data, who should it apply to (vessel size, vessel trade, unilaterally etc.), how to allocate emissions allowances, how to administer the system, how to pay for administrative expenses, other costs related to an active market (transaction costs etc.), what to do with any revenue generated etc. All of these issues and more must be understood and addressed before an ETS can become a feasible solution to the problem. These issues and potential methods to deal with them will be further investigated in subsequent chapters of this study.

5.3 CO₂ Index for Ships

5.3.1 Overview

The following excerpt from a study conducted by Matthew Donatelli in the spring of 2008 provides a very brief background for the continuously-evolving CO₂ indexing scheme for ships. Note that this study was prior to the MEPC 58th session and that little progress had been made in distinguishing between a design index and an operation index.

"... MEPC/Circ.471 offered a flexible set of guidelines for developing a CO₂ index for ships. This document also invited, "industry, organizations, and interested

Administrations,” to use these guidelines for trial and offer input back to MEPC 58 (to be held in October of 2008). Because the quantity of CO2 emitted is a function of the amount of fuel consumed in any carbon-based combustion process, the proposed index can also serve as a vessel performance rating of fuel efficiency. More specifically, the index is calculated to quantify energy efficiency in terms of CO2 emitted per unit of transport work (IMO, MEPC/Cir.471). In the MEPC Interim Guidelines for Voluntary Ship CO2 Emission Indexing for Use in Trials, this index is explicitly given to take the form shown below.

$$\text{Index} = m_{\text{co}_2} / (\text{transport work})$$

Where m_{co_2} is the mass rate (grams/hour) of CO2 emitted. As mentioned before, the amount of CO2 emitted is directly related to fuel consumption (FC) which MEPC defines to be all fuel consumed both underway and in port during the period of evaluation. The calculation of transport work, most appropriately in the form of tonne-miles (or their equivalent) is more vaguely defined. Logically, transport work is then a function of distance traveled and amount of cargo carried.”

While ongoing discussion and technical comment has been offered by many member governments, the fundamental idea remains to index ships based on the ratio of their CO₂ emissions levels to the benefit they offer, taken as the product of the cargo they move and how far they move it. Table 6: Document Summary: MEPC 58th Session (GHG Issues), above illustrates, at a glance, the types of technical comment that has been offered. These include everything from corrective coefficients for ice-strengthened vessels, to auxiliary power considerations and suggestions for monitoring and verification.

At the MEPC 58th session, the design index that has been developed from MEP/Cir.471, now known as the Energy Efficiency Design Index (EEDI) has been set for trial application by calculation. Results from this trial are to be further discussed at an intersessional working group meeting scheduled for March 2009. An operational version of the index, now referred to as the Energy Efficiency Operational Index (EEOI) is still under consideration and will be subject to review at the March 2009 meeting.

5.3.2 Potential Effectiveness and Limitations

While technical response has been abundant and productive, it appears that there is underdeveloped link between the indexing scheme(s) and how they could serve as an effective mechanism to reduce international shipping emissions. Furthermore, a design index would require a significant amount of time before measurable benefits are realized (assuming grandfathering of existing vessels). An operational index could be used as a metric for quantitatively characterizing compliance or assessing penalty, possibly in the form of a port tax etc. However, there is a great risk that strict enforcement of either index may actually cause the need for more ships or cause ships to operate outside of their conventional trade routines. This could potentially result in greater aggregate ship air emissions than the status quo. Thus, without supplementary measures, is an indexing scheme capable of regulating an absolute bound on ship emissions? It has been pointed out that if an index were approved and applied to all ships involved in international trade, the IMO (or some other central body) would have a means to establish a baseline for efficiency of the world fleet.

As with other proposed approaches, the notion of common but differentiated responsibility has already arisen with regard to whom the index should apply. In order for the scheme to be effective it must reduce global emissions from the shipping industry, however, developing countries continue to defend their appeal for exemption. This issue, along with others such as measuring, recording, and verifying emissions data, is examined more closely in the subsequent chapters of this study.

5.4 Alternative Approaches

5.4.1 Overview

As mentioned earlier, the two other major approaches that have been proposed are a levy on fuel and various 'hybrid' concepts which combine components of a couple types of systems. In theory a fuel levy is simple; since the ship's fuel is the source of its emissions, associating an additional charge with the price of the fuel holds ship operators responsible for their emissions. In order for this to be practical there are a number of hurdles which must first be overcome. This includes the common but differentiated responsibility debate and whether or not this would apply to all ships.

As for hybrid plans, these are approaches comprised of any number of combinations of the mechanisms which have been and continue to be discussed through the IMO. While this idea has been suggested, there have not been any very detailed proposals of a hybrid system. Logically, this is because each of the other mechanisms is still being thought through, developed, and evaluated. An example of a hybrid concept would be to use a design index as

regulatory guidance during the design phase of the ship and then to use an operational index as a metric in part of a shipping ETS.

5.4.2 Potential Effectiveness and Limitations

The ability of a fuel levy to reduce ship air emissions is questionable. While a levy on bunkers would hold ship operators responsible for their emissions (as the 'price' of CO₂ emissions would be passed down), this mechanism has no real control over the absolute level of emissions. Additional issues inherent to this plan include administration responsibility, legal concerns for standardized international application, and concerns about an unjustified modal shift in cargo movement. For any potential hybrid plans, issues inherent to the components parts of the program (discussed above) are inherently adopted. These issues will be examined more closely in subsequent chapters of this study.

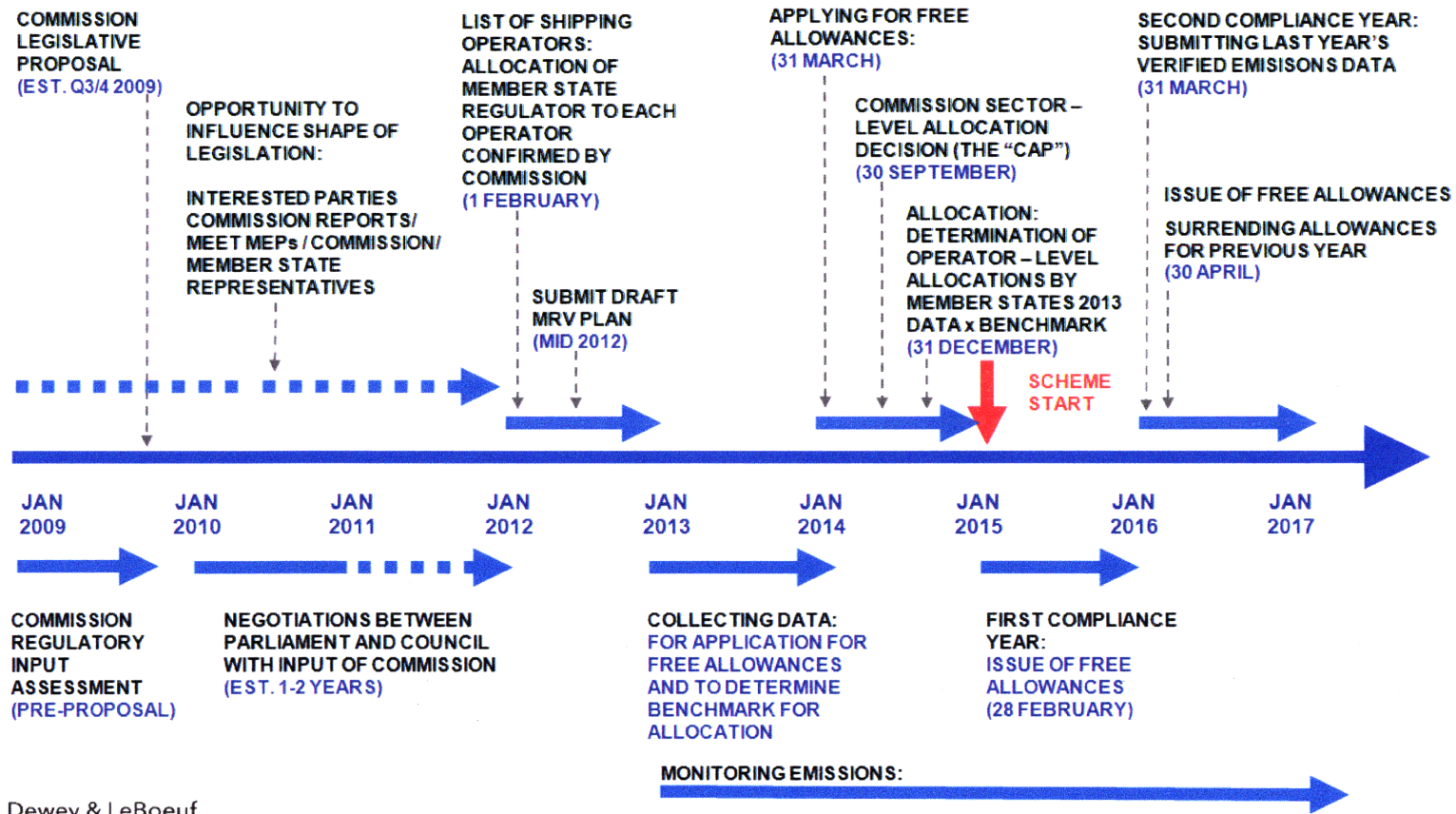
5.5 Conclusion

The shipping community recognizes that international cooperation is essential in developing a practical, feasible, and effective system for the reduction of ship air emissions. The ongoing development and discussion within the IMO, and specifically the MEPC, is serving as the vehicle to synthesize the proposed ideas of any participating member governments of the IMO. This work has been the source of the systems noted above, and will continue to mold the needs of the shipping community into a program suitable for the reduction of ship air emissions. However, as indicated in the text above there are a number of issues that require further attention prior to implementing a system for the maritime industry. Many of these, including monitoring, recording, and enforcement issues as well as administrative and

infrastructure issues will be considered in subsequent chapters of this study. Also there will be further discussion of solutions which (against intuition) may lead to evasive results and an increase in overall emissions versus programs that have the potential to promote a real reduction in ship air emissions. It is also worth noting that automobile manufacturers in the United States face environmental regulations based on the theoretical output of their engines while the shipping industry seems to be focused on the actual operating conditions of vessels. The operating output is not only more difficult to measure and enforce, but regulating the actual output of vessels is also a disadvantage to ship operators.

It must also be noted that the work being done through the IMO under constant pressure by the European Union. The European Union has made it clear that they intend to take matters into their own hands should the IMO not continue to demonstrate that substantial progress is being made towards the implementation of greenhouse gas reducing measures. The timeline in Figure 4, from a presentation by Nicholas Rock of *Dewey & LeBoeuf* [48], illustrates the potential timeframe in which the EU plans to develop and implement its own system through Brussels. Note that the system would commence by 2015.

Figure 4: Potential EU Timeline



Dewey & LeBoeuf

6.0 Chapter 6: Unresolved Issues for At-Sea Application

6.1 Overview

Chapter 5.0 explored the various types of systems that are currently being considered for maritime application and noted that there are a plethora of issues associated with each type of system. To most relevantly address these issues, this section has organized them into an assortment of higher-level, system-generic concerns. These are the critical issues that must be discussed, understood, and overcome in order for successful application of a market-based system for the shipping community. Within each of these macro-issues there resides a dynamic subset of issues that will continue to evolve as a particular system is honed in on. For this reason, thorough and practical discussion and speculation is absolutely essential to defining a system which is able to meet the very specialized needs of the maritime industry.

6.2 Meaningful System vs. Political Satisfaction

Many of the issues previously noted question what it will take to implement a market-based system capable of achieving real, and meaningful, reduction in ship air emissions. Amidst all of the convoluted legs of this discussion it must not be neglected that this, after all, is the fundamental reason for developing and using such a system. To clarify, the term 'real' reduction means reducing the total air emissions associated with the world fleet (a very difficult number to keep track of which this chapter elaborates upon). The term 'meaningful' reduction implies that the level of reduction corresponds to scientifically determined expectations for a safe and sustainable environment. While the shipping community can work towards achieving real reductions, meaningful reductions is another whole debate outside of the scope of this

work. Frankly, any evolution in that debate is not likely to alter the current discussion within the maritime industry.

Perhaps the most significant ongoing debate relevant to this issue is regarding the notion of common but differentiated responsibility. Supporters of this idea defend that only member states included in the United Nations Framework Convention for Climate Change (UNFCCC) Annex I should be regulated by any new emissions system [15]. The countries included under UNFCCC Annex I are listed below in Table 7 [30].

Table 7: UNFCCC Annex I Parties

Australia	Liechtenstein
Austria	Lithuania
Belarus	Luxembourg
Belgium	Monaco
Bulgaria	Netherlands
Canada	New Zealand
Croatia	Norway
Czech Republic	Poland
Denmark	Portugal
Estonia	Romania
European Community	Russian Federation
Finland	Slovakia
France	Slovenia

Germany	Spain
Greece	Sweden
Hungary	Switzerland
Iceland	Turkey
Ireland	Ukraine
Italy	United Kingdom
Japan	United States of America
Latvia	

Without even distinguishing between which countries are and are not included in this list, it is intuitive that a system which applies only to certain countries does not have the ability to control air emissions from the entire shipping community. This is common sense; whether or not this is to make regulations fairer to developing countries, focus on the actual objective of this system must not be lost. Clearly this would void the original objective. In the previously established IMO Convention for the Prevention of Pollution from Ships, MARPOL Annex VI, non-discriminatory treatment was achieved by the inclusion of a, “no more favorable” clause. MARPOL Annex VI deals, in particular, with the reduction of NO_x and SO_x emissions. Lastly, and not to harp on a seemingly straight-forward point, members not listed under Annex I account for more than 2/3 of the world fleet (greater than 400 gross tons). This is shown below in Table 8 [53].

Table 8: Distribution of the World Fleet (March 2008)

For Ships Above 400 GT

	Number of Ships	GT	DW
Annex I Flag States	20,872 (33.42%)	209,015,681 (26.08%)	263,820,104 (22.82%)
Non-Annex I Flag States	41,119 (66.58%)	593,330,359 (73.92%)	892,384,249 (77.18%)
Total	61,862	801,346,040	1,156,204,353

6.3 Emissions Monitoring and Enforcement

Given the existing infrastructure and the complex international nature of this industry, monitoring and enforcement of any new system will certainly prove to be a complicated and tedious task. The first, and most straight-forward, concern is: how to collect emissions data from ships? A practical solution may be to have ship operators record and submit fuel consumption data for all ships in their fleets. The amount of CO₂ emissions could then be calculated relatively accurately based on the grade of fuel being used (from its chemical composition). While most, if not all, ships are already capable of tracking their fuel consumption, there are still a few difficulties with this approach. First, it is not 100% accurate as some error will arise in calculation (and variation in fuel properties/ actual onboard conditions). Also, there would be a great amount of effort, and a certain level of trust, associated with ensuring compliance. This would likely require some responsible third party to conduct inspections, audits, etc.

For these reasons, it is not far-fetched to speculate that the most appropriate way to monitor emissions is to use CO₂ measurement devices on the stacks of ships. In contrast to the

previous idea, few if any ships are currently equipped to do this. Thus, this method would require a significant initial investment in infrastructure upgrading. While this is merely an idea, not yet accompanied by a cost estimate, its impact would certainly be substantial as it affects all ships. However, with such a system in place, there would be a relatively simple, unbiased means of measuring and recording emissions data. Further, with today's technology capabilities, data from ships could easily be transmitted to and compiled by whatever central body is governing the system. More comment on infrastructure is offered in the next section, Establishing and Sustaining Infrastructure.

Another issue that further complicates enforcement is that cargo movement in the maritime industry is not always a clearly-defined origin to destination trip. Cross-dock and transshipped cargoes void some of the previously mentioned methodologies for other industries such as the airline industry. For example, whereas a flight may be assessed a certain surcharge based on its origin to destination (hypothetically), a ship is likely carrying cargoes from multiple origin-destination pairs that may have also changed ship one or more times. Due to this complexity, a simplified system which associates emissions responsibility with origin-destination travel is seemingly not feasible, and certainly not practical, for the shipping industry. It should also be noted that some simplified approaches must be thoroughly evaluated to avoid loopholes which may be taken advantage of. Consider, for instance, a system which charges a certain landing fee to all flights landing in a European airport based on the distance from their point of origin; however, there is no fee for flights landing in non-European airports (again hypothetical). It seems obvious that flight trends into this European

airport would quickly shift to multi-leg trips with the first leg covering as much distance as possible between two unregulated airports. While this is a hypothetical situation for the aviation industry, it is easy to see that similar loopholes have potential to be even more vulnerable in the maritime industry. This issue provides good insight, and a perfect segue, into the Tradeoff Considerations section later in this chapter.

6.4 Establishing and Sustaining Infrastructure

Another large uncertainty in the development of a new system is: who will build and manage the infrastructure necessary to maintain this system? A centralized organization to administer the new system is clearly a prerequisite for all of the systems under consideration. The specialized functions of this administration will continue to be defined as a system is finalized and applied. For this reason, infrastructure considerations have been widely acknowledged, but seem to continually be placed on the backburner.

Beyond a centralized administration, which will inevitably require significant investment of time and money, other infrastructure needs will arise that will more directly impact ship operators. If a system is based on trading carbon credits or allowances, all operators will have to manage their credits. This could have a number of implications for the industry. In the simplest sense, any ship operating company would then have to dedicate some portion of their manpower to monitoring their fleet's emissions, ensuring compliance to regulation, and also trading excess allowances or acquiring additional allowances. This responsibility would likely scale with the size of the company. For instance, a small company might only require minimal additional time from existing personnel whereas a very large company, with many ships, might

need to create new positions dedicated to emissions management. This issue is also noted in the Cost to Ship Owners and Operators section below.

Aside from the direct cost to ship owners and operators, the administering party for this system would also require substantial financial support. At this stage of development, it is difficult to accurately speculate on these costs. However, revenue from a market-based system could be used to support administration of the system. Thus, while credit or allowance prices may be dictated by market demand, administrative costs would likely have a role in transactional fees for the system. To facilitate transactions in this market, it is likely, if not certain, that third-party brokers would emerge. This adds another piece to the infrastructure development as well as additional fees associated with transactions. These issues will require further consideration as the details of the system evolve and better financial forecasts are made.

6.5 Cost to Ship Owners and Operators

As with many of the major issues in this chapter, it is quite difficult to predict the fine details at this point. However, it would be naïve not to realize that a market-based system will bring added cost to ship owners and operators. This is especially true during the startup of the system where the fine details will still be malleable and while the learning curve is steep. As mentioned in the previous section about infrastructure, the severity of financial strain placed on owners and operators will likely take on some trend of direct proportionality to the fleet size. Other factors that could affect expenses are the age of the fleet and condition of equipment as well as trade patterns and operational conditions. These are parameters which

could drive the emissions levels of the fleet and ultimately dictate the penalties a company incurs. So, the cost to operators can be thought of in terms of two major categories: internal management of emissions and the actual 'cost' of emitting (where the 'cost' of emitting could actually be profit should emissions levels be lower than the allowed level). The next section, Tradeoff Considerations, discusses how these costs may affect ship building, equipment conditions, trade patterns, and operating parameters. Lastly, some cost speculation from a presentation by the Chemical and Air Pollution Prevention Section of the IMO's Marine Environment Division place some stamp of magnitude on the costs associated with current emissions levels [53]. From this presentation

Table 9: CO₂ Emissions from Ships in 2007 [53]

	Million tonnes
Total Inventory	1019
Domestic/Fishing	-176
International Shipping	843
High Estimate: 1052	Assessed uncertainty >+/- 20%
Low Estimate: 682	May Improve with better activity data

Table 10: Estimated Growth [53]

2020	By a factor of 1.1 to 1.3
2050	By a factor of 2.5 to 3.0

Thus, using the EU ETS carbon price of €19/million tonne (October 2008 [53]) or about \$23 US (€1 = just over \$1.2 US in October 2008 [8]), the total 'cost' of emissions from international shipping in 2007 would have been about \$19.4B US.

6.6 Tradeoff Considerations

This study has identified four major tradeoffs that must not be neglected in the development of a market-based system. These tradeoffs are as follows:

- Tradeoff between NO_x/SO_x emissions and CO₂ emissions
- Tradeoff between burning higher-grade fuel and manufacturing higher-grade fuel
- Tradeoff between life cycle analysis (including building and scrapping) of new ships vs. improved operational performance
- Tradeoff between shipping regulations and modal share in cargo movement

Especially with the recent work done and regulation passed for NO_x and SO_x emissions, it is important to consider how NO_x/SO_x reduction is interrelated to the reduction of CO₂ emissions. During the formation of MARPOL Annex VI, the revised version of which goes into effect on July 1st, 2010 [15], this tradeoff was considered. Annex VI focuses on NO_x/SO_x emissions, however, and though the issue was considered, no consensus was reached in terms of quantitative analysis. One complication in this evaluation is that continuously evolving technology is constantly changing the technical parameters of the analysis. Apart from the rest of the technical analysis, it is certain that human health is paramount and takes precedent over ecological concerns.

While burning better fuel (more refined) definitely has potential to improve NOx and SOx emissions from ships, the counterpart is that this benefit must be balanced with the negative impact resulting from the manufacturing of more refined fuels. Simply stated, if more pollution is emitted during the land-based manufacturing process than is saved by ships burning the better fuel, there is still a net negative impact on the environment. With that said, in the shipping industry, a lot of reduction in emissions can be achieved for a relatively low price. This is in part due to the low quality of residual fuel that is currently burned. It should also be noted that some analysis has been done to compare the ship vs. land-based savings; however, these efforts have focused on the cost of building new refineries rather than considering the benefit of upgrading existing facilities. At this point, there is no evident consensus on this issue.

In a similar sense to the previous issues, consideration, but not much analysis has been done to include the full life cycle of the ship. If ships are slowed down to emit less CO₂, more ships will be needed. In particular, each ship will require construction and scrapping; these issues must be included when accurately evaluating the overall efficiency performance of a ship. Again, if more CO₂ is emitted during the production of a highly-efficient ship than is saved during the operation of that ship, there could still be a net negative impact on the environment. To draw an analogy, this is similar to the popular argument that more harm is done in manufacturing some hybrid cars, such as the Toyota Prius, than is regained by its operational benefits (this is not a proven fact, but rather a debatable argument subject to the method in which the analysis is carried out). Aside from the ship vs. land tradeoff, this opens the door to an entirely new set of dynamic considerations for ship owners when building new vessels.

When an owner decides to build a new ship, he/she will want to optimize its design for performance in a certain trade. For instance, if the ship will become part of a trade loop with two existing ships, the design may be optimized to a certain speed which is dictated by the destinations in the trade loop and the speed of the existing ships. This is particularly important because the natural instinct for operators is to slow down their ships to achieve better efficiency. Intuitively, if the ships are operating at reduced speeds, additional ships may be required to maintain the same trade schedule. This also gives rise to the question of how much decrease in speed is possible without leaving the engine's window of efficiency. In terms of new build considerations, one must recognize the importance of fleet interdependence for optimization scenarios.

The fourth major consideration is the regulation of various transport modes and the impact of biased regulation on the modal split of cargo movement. As regulation for the shipping industry is developed, the regulation of other industries must be considered so as to avoid creating an unfair attraction towards one mode of transportation versus another. For instance, if shipping regulations are so harsh that it becomes more economic to move cargo by truck (where possible), this could potentially create an unnatural shift in mode share. This concern is particularly relevant to smaller, specialized markets such as the Great Lakes region in the United States. Currently this argument is alive in Europe, but lacks a very thorough analysis.

6.7 Maritime ETS Considerations

Intellectually, many seem to support the concept of an emissions trading scheme for the marine industry. However, from a practical standpoint, those same supporters don't yet have

answers to some of the fundamental, but daunting issues (like the ones addressed above). Another large question, perhaps with an easier answer, is whether the system should be open or closed. An open system would have the ability to interact with other industries whereas a closed system would be exclusive to the shipping community. Reasoning based on the overall goal of global CO₂ emissions reduction suggests that an open system is more logical. How could real reduction be achieved if only certain players participate? However, in all practicality, it is unreasonably optimistic to think that a global system can start in an instant. Thus, a maritime ETS would almost inevitably begin as a closed system.

Another issue requiring further consideration is the allocation of credits. As this study has noted, this can be done (and has been done in other industries) in a few different ways. Allowances could be allocated based on historical trends and a target reduction, they could be partially allocated against a pre-determined baseline, or they could be entirely auctioned. Regardless of the method chosen, careful attention must be paid to avoid the implications of political bias amongst member countries. Also, and particularly in the all-auctioned case, some provisions must be taken to protect new entrants. In general, a maritime ETS poses the risk of hindering growth and/or creating prohibitive conditions for new entrants if administration, allocation, auctioning etc. is not properly designed for the system.

6.8 Design and Operational Index Issues

In comparison to the other issues identified in this study, CO₂ design and operational indices have already undergone significant discussion and progress through the IMO MEPC. Previously mentioned, the IMO has agreed upon interim guidelines for the Energy Efficiency

Design Index (EEDI). The Energy Efficiency Operational Index is currently under further work to be reported on at the 59th MEPC session in July 2009. In terms of these indices, more people are comfortable with the concept of a design index than of an operational index. This is quite possibly why the design index has seen more rapid progression. The remainder of the work for developing the design index lies in fine tuning the formula. On the contrary, not many people seem to be as comfortable with the operational index. This is because an operational index is subject to an infinitely variable set of parameters. Actual conditions, for example heavy weather, can affect this index.

At this point, it is not certain how the design or operational indices will be used or if they will be incorporated into a market-based system. Regardless of their specific use, the difference between inherent (design) efficiency and actual efficiency must be acknowledged. The design efficiency is analogous to the published 'efficiencies' in the automotive industry where we understand that the actual efficiency will vary. In this case, the design index may be suitable for use in future design standards; however, this would require further discussion and is merely speculation at this point.

6.9 Conclusions

At present, because there has not yet been consensus on which type of system to implement, the generic issues are arguably more urgent for consideration. These issues have been put into a loose timeframe perspective in Chapter 8.0, Recommendations, of this study. As has been a recurring theme in this study, this chapter has provided additional insight into the numerous and continually-evolving issues associated with initiating a new system.

However, the largest and most critical issue, particularly at this stage of discussion, is creating a meaningful system vs. political satisfaction (considered in Section 6.2).

7.0 Chapter 7: Conclusions and Recommendations

7.1 Conclusions

This study has investigated a market-based approach for improving ship air emissions. This has been done in three very distinct segments of the report: First, existing systems for other industries, including land-based and aviation, were considered. Next, existing and proposed systems for the shipping industry were looked at. Lastly, a number of issues, mostly higher-level issues, were identified for consideration during the current development of a maritime system. The study progressed using the fundamental definition of a market-based system to be: a system which implements economic incentives to prompt or stimulate some reduction in air emissions. The 1997 Kyoto Protocol, stemming from the work of the United Nations Framework Convention for Climate Change (1992), called for signatories to actively begin reducing CO₂ emissions. However, due to the complexity added by its international nature, the shipping industry (as well the aviation industry), was excluded from the initial call to action. With that said, the International Maritime Organization (IMO) had been considering the issue for some time and intends to implement a framework for GHG emissions reductions prior to the Kyoto Protocol's first commitment period in 2011. It should also be noted that at present, there is significant pressure being put on the IMO to act prior to the European Union initiating its own measures.

Chapter 2: Evaluation of Market-Based Systems Applied to Other Industries identified a number of systems currently in use to reduce CO₂ emissions. Amongst these systems, the European Union's Emissions Trading Scheme (EU ETS) arguably has the greatest scope and has

potential for real reduction and lasting effect. Further, it appears that the aviation industry is largely in consensus that joining with the EU ETS is the most reasonable course of action. The details of this system are not yet fully developed. In particular, the administrative and transactional costs are unknown.

This study also identified some systems which are used on a smaller scale within the maritime industry to promote improvement ship air emissions reductions. Systems like the Port of Long Beach/Port of Los Angeles Green Flag Program have demonstrated their acceptance (within the community) and success, but are confined in scope to localized application. Next, the current work within the IMO's Marine Environment Protection Committee (MEPC) was considered, and the report investigated the potential of an emissions trading scheme for the shipping industry, the use of a CO₂ indexing scheme, and the use of an alternative or hybrid system. To put these notions into perspective with each other, an ETS and alternative/hybrid systems are current rivals of debate within the shipping community while the CO₂ index has developed simultaneously alongside. At the MEPC 58th session in October of 2008, IMO developed guidelines for an energy efficiency design index (EEDI) and an energy efficiency operational index (EEOI), an efficiency management plan for ships, and a voluntary code for best practice in energy-efficient operation [15]. While additional work in 2009 is expected to bring further progress of the EEOI, interim guidelines for the EEDI calculations were issued for trial use and will be subject to ongoing refinement.

In addition to the CO₂ indices, IMO will further discuss market-based systems in early 2009 and report to the MEPC 59th session in July 2009. The work done at the July meeting will

subsequently be presented at the United Nations conference in Copenhagen during December of 2009. Throughout the upcoming months and into the next couple of years, IMO must continue to show that substantial progress is being made towards reducing greenhouse gases from ship emissions. It is also critical that the shipping community work towards incorporating developing countries into the proposed system by the 2012 Copenhagen meeting (when the Kyoto Protocol expires). During this time, IMO will remain under the pressure of the EU (see Figure 4: Potential EU Timeline). This study has shown that an independent or an integrated emissions trading scheme for the shipping industry has potential for establishing meaningful and real reduction in CO₂ emissions from ships. Further, some ship owners favor integrating shipping into an economy-wide ETS. This is because shipping is relatively efficient, so ship owners would be net sellers of credits. However, since current discussions are for closed systems, ship owners would not gain such an advantage. Furthermore, developing and implementing an emissions trading scheme for the maritime industry will prove to be a slow process as it is heavily burdened with infrastructure issues. It would certainly require a very patient transition. With that said, it would put the shipping industry on par with the efforts being taken in other parts of the world and in other industries.

Instead of an ETS, an alternative or hybrid approach could offer some different benefits, but also comes with its own set of challenging developmental issues. There is significant support for the implementation of a fuel bunker levy type system. Arguably the strongest argument in favor of this type of system is that the revenue from the taxes could be used for research and development of new technology for sustainable, environmentally-conscious

shipping. There are a few major issues with this idea. First, the infrastructure needed to administer, manage the system, and re-invest revenue in technology would be substantial. Also, as mentioned earlier, the system would need to carefully consider how to establish a net reduction in emission while avoiding a simple price increase and absorption within the industry. One idea that could make a hybrid levy system more feasible is to incorporate an incentivized reduction schedule. For instance, the first year of emissions would be recorded and taxed. The next year, however, taxes would be assessed at the normal rate for all emissions of equal or lesser quantity than the previous year, and any excess emissions would be subject to a greater tax rate.

Regardless of the chosen approach, this study has illustrated that there is a whole slew of higher-level issues and tradeoffs that will require much additional consideration prior to implementation. With regard to establishing a system capable of real reduction in emissions, it is critical that the developing countries be incorporated in the system at some level. This means that ongoing discussions for market-based systems must challenge the notion of common, but differentiated responsibility. Further, the infrastructure needs for a new system are great. These range from administering and enforcing the system to establishing and maintaining a market to the potential need for new monitoring equipment aboard vessels. The extent of these additional infrastructure needs, as well as the associated costs, is not yet understood. Certainly these needs will translate directly into increased operational costs for vessel operators. Other costs, such as transactional costs and the actual pricing of emissions are not yet understood either. The study also identified a handful of important tradeoff

considerations. These include: the interdependence and relationship between regulating NO_x/SO_x emissions and CO₂ emissions, the balance between burning higher-grade fuel and increased effort in land-based refineries, lifecycle considerations including building and scrapping of the vessel as well as slowing down ships to reduce emissions and the associated potential need for more ships to maintain trade patterns, and the modal share of cargo movement. A recurring theme amongst these tradeoffs is that a meaningful system for the shipping industry is not possible without considering how it will interact and interface within the broader context of global system for the reduction of emissions from all sources worldwide. In general, there has been a lack of attention paid to this interaction. Discussions within the shipping industry have primarily (if not exclusively) considered the maritime community as an isolated entity. With such potentially massive investments in time, infrastructure, and operating expenses, it is important that the shipping industry understands the long-term potential and implications of its system within a much larger global effort.

Up to this point the shipping industry, via the IMO, has shown adequate consideration, discussion, and development of CO₂ reducing measures to maintain control of the issue. However, under the pressure of the European Union and alongside the progress in other industries, the shipping industry must soon demonstrate that it has developed and is ready to implement a meaningful tool to responsibly regulate CO₂ emissions. As this study has indicated, some of the smaller steps that have been taken have been sufficient demonstrators of industry progress, but it is now time to prepare for and initiate an appropriate strategy that is effective, beneficial, and worthwhile in the long run.

7.2 Recommendations

It is important that ship owners and operators recognize that the developing regulatory work is a real issue that will significantly affect their operations in the very near future. While a number of owners and operators are active and have been active in the development process, some may not be aware of the complete scope of this discussion. Thus, Table 11 and Table 12 consolidate much of the information in this study into an itemized list of recommended actions for ship owners and operators.

In general, the motivation and progress thus far are clear evidence that regulation can be expected in the near future. Further, pressure from the EU makes it very likely that some formal regulation will be in place, or at least proposed, sometime between 2012-2015. Thus, it is critical that all facets of the shipping industry, from classification societies to individual owners, remain active in the development of these regulations while they are still very malleable. As Chapter 6.0 indicated, many large concerns remain unresolved. It is to the advantage of the industry to thoroughly consider how possible scenarios (such as those investigated in this study) might affect their day-to-day operations and for them to challenge issues from their own perspective where necessary. How will this change the interaction between shipyards, vessel owners, ship management companies, etc.? Individual companies have the most comprehensive understanding of their own particular role within the shipping community, and it is left to their input to insure that their needs within this system not be overlooked. Finally, as a general recommendation to the industry, discussions regarding market-based approaches should extend beyond the isolated impact within the maritime

community in order to fully acknowledge and contemplate the effectiveness, interaction, tradeoffs, and the role which potential maritime systems could play within the context of a global effort. This is true regardless of whether or not a system for the shipping industry begins as an open or closed system.

Even during this developmental stage, there are a number of preemptive steps which ship operators can take to ease the transition into emissions management. The first of which is to simply remain aware of current developments and discussions. It is also useful to observe the impact that emissions reduction efforts have had on other industries, but to recognize the unique needs and particular complexity of the shipping industry. This study provides a solid investigation of these issues. Also, while no consensus has been reached for the type of system to be used, it will be helpful to participate in any of the trial guidelines which are established by the IMO. One particular benefit to these trials is that they can be used to understand where a vessel, or an entire fleet, stands relative to other vessels and fleets by comparing against other collected data. This comparison could be an exceptionally valuable indicator of relative future expense implications. It could also provide insight and perspective for long-term strategic planning for operators. Along these lines, it is also useful to upgrade technology as appropriate, but to recognize that such modernization may help, but likely not provide exemption from future regulations. Lastly, while absolute expenses are not yet understood, it is reasonable to prepare for some level of increased operational expenses. These costs will likely scale directly with the size of the fleet and the age of the vessels and equipment. The above-mentioned steps towards emissions management are itemized below in Table 12.

Table 11: Recommended Actions for Ship Operators: Timeline

Remaining Active in the Development Process
March 2009: Intersessional GHG Working Group Meeting
July 2009: IMO MEPC 59th Session
December 2009: United Nations Conference on Climate Change – Copenhagen
2012: Kyoto Protocol Expires

Table 12: Recommended Actions for Ship Operators: Considerations

Preemptive Measures Towards Emissions Management
<ul style="list-style-type: none">• Keep management team familiar with current developments (and up to date on background info)
<ul style="list-style-type: none">• Observe how market-based CO₂ reduction tools have affected other industries (continue to monitor aviation industry)
<ul style="list-style-type: none">• Participate in trial guidelines both to ease the learning curve and offer critical feedback
<ul style="list-style-type: none">• Understand where your fleet compares to other ships (check against reported data for trial use)
<ul style="list-style-type: none">• Upgrade technology where practical, but don't assume that this will result in exemption (even for developing countries)
<ul style="list-style-type: none">• Brace for some degree of increased operational costs as well as management costs (particularly for large fleets and/or fleets with older vessels and engines)
<ul style="list-style-type: none">• Consider opportunities that exist (such as trading credits) both internal to fleet or externally and how these interactions may be affected by final regulations

Selected Bibliography

- [1] "Allocation and Related Issues for Post-2012 Phases of the EU ETS." Directorate General Environment, European Commission. 22 October 2007.
http://ec.europa.eu/environment/climat/pdf/post_2012_allocation_nera.pdf.
- [2] "Board Approves Green Flag Dockage Rates." The Port of Long Beach News Release. 2 March 2006.
- [3] "Cap-And-Trade Proponents Wait Out Bush." Aviation Week. 6 June 2008.
<http://www.aviationweek.com/aw/>.
- [4] "Clean Air Markets." United States Environmental Protection Agency.
<http://www.epa.gov/airmarkets/index.html>.
- [5] "Emission Trading in the EU." Climate Action Network Europe.
<http://www.climnet.org/EUenergy/ET.html>.
- [6] "Emissions and Allowance Tracking." Regional Greenhouse Gas Initiative.
<http://www.rggi.org/tracking>.
- [7] "EU Tells US Airlines to Pay for Their Carbon Emissions or Lose Flights to Europe." Wired. 14 April, 2008. <http://blog.wired.com/cars/2008/04/post.html>.
- [8] "Euro Foreign Exchange Reference Rates." European Central Bank. March 2009.
<http://www.ecb.int/home/html/index.en.html>.
- [9] "Europe Forcing Airlines to Buy Emissions Permits." The New York Times. 24 October 2008.
<http://www.nytimes.com/2008/10/25/business/worldbusiness/25emissions.html?ref=business>.
- [10] "European Union Emissions Trading Scheme." Wikipedia. October 2008.
http://en.wikipedia.org/wiki/European_Union_Emission_Trading_Scheme.
- [11] "Global Airlines Blast EU ETS Decision." EurActiv. 27 October 2008.
<http://www.euractiv.com/en/transport/global-airlines-blast-eu-ets-decision/article-176679>.
- [12] "IMO Reports Progress on Vessel Energy Efficiency." The Maritime Reporter and Engineering News. 17 March 2009. <http://marinelink.com/en-US/News/default.aspx>.
- [13] "Information Concerning New Fairway Dues." Swedish Maritime Administration. 10 September 2004.
- [14] "International Regulation News Update: Marine Environment Protection Committee's 58th Session." Vol. 17, No. 3. ABS Regulatory Affairs. November 2008.
- [15] "Major progress on air pollution, ship recycling and ballast water management at IMO environmental meeting." No. 4, 2008. IMO News.
- [16] "Marine Vessels and Ports Sector." West Coast Collaborative.
<http://www.westcoastdiesel.org/wkgrp-marine.htm>.
- [17] "Note by the International Maritime Organization: Input to the FCCC/AWGLCA/2008/16 – The Assembly Document." International Maritime Organization.
- [18] "Press Releases RAPID." Europa: The European Union On-Line. 08 March 2005.
<http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/05/84&format=HTML&aged=1&language=EN&guiLanguage=en>.

- [19] "Press Releases RAPID." Europa: The European Union On-Line. 20 December 2006.
<http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/1862&format=HTML&aged=0%3Cuage=EN&guiLanguage=en>.
- [20] "Proposal for a Directive of the European Parliament and of the Council." 20 December 2006. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0818:FIN:EN:PDF>.
- [21] "Regional Clean Air Incentives Market (RECLAIM)." South Coast Air Quality Management District. <http://www.aqmd.gov/RECLAIM/reclaim.html>.
- [22] "Regional Clean Air Incentives Market." Wikipedia. October 2008.
http://en.wikipedia.org/wiki/Regional_Clean_Air_Incentives_Market.
- [23] "Regional Greenhouse Gas Initiative Model Rule." 5 January 2007.
http://www.rggi.org/docs/model_rule_corrected_1_5_07.pdf
- [24] "Regional Greenhouse Gas Initiative." Wikipedia. October 2008.
http://en.wikipedia.org/wiki/Regional_Greenhouse_Gas_Initiative.
- [25] "Regional Greenhouse Gas Initiative: Frequently Asked Questions."
http://www.rggi.org/docs/mou_faqs_12_20_05.pdf.
- [26] "RGGI-COATS User's Guide for Version 1.2." 25 September 2008. http://www.rggi-coats.org/eats/rggi/image/help/_rggi/RGGIGettingStartedGuide.pdf.
- [27] "Shipping's Burden." *Surveyor*. Fall 2008.
- [28] "Something in the Air." *Surveyor*. Fall 2008.
- [29] "Study of Greenhouse Gas Emissions from Ships." Norwegian Marine Technology Research Institute. March 2000.
http://unfccc.int/files/methods_and_science/emissions_from_intl_transport/application/pdf/imoghmain.pdf.
- [30] "United Nations Framework Convention on Climate Change." March 2009.
<http://unfccc.int/>.
- [31] Baron, Richard et al. "International Emission Trading: From Concept to Reality." International Energy Agency. 2001.
- [32] Brett, Bridget. "Economic Incentives for Ship Emissions Reductions." Massachusetts Institute of Technology. May 2008.
- [33] Bruning, Kristian and Jeff Cohen. "Beyond the Kyoto Six." <http://www.carbon-financeonline.com/index.cfm?section=features&id=11092&action=view&return=home>.
- [34] Bryn, Peter. "Key Issues for a Greenhouse Gas Cap and Trade Program Imposed on the Maritime Industry." Massachusetts Institute of Technology. 1 May 2007.
- [35] Department for Environment Food and Rural Affairs.
<http://www.defra.gov.uk/Environment/climatechange/trading/index.htm>.
- [36] Dickinsson, Joanna. "Regulations and Means of Control to Reduce Environmental Impact of Freight Transport: A Benchmarking Study Within Sweden and EU." May 2006.
http://www.cpm.chalmers.se/document/reports/06/CPM%20Report%202006_9%20rapport_regulations.pdf.
- [37] Documents submitted for Marine Environment Protection Committee (MEPC) 58th Session. International Maritime Organization. October 2008.

- [38] Donatelli, Matthew. "Evolving CO₂ Emissions Regulation Policy for the Marine Industry: Potential Impact on Ship Design and Operation." Webb Institute. 18 April 2008.
- [39] Ellerman, Denny A. and Barbara Buchner. Oxford Journals. "The European Union Emissions Trading Scheme: Origins, Allocation, and Early Results." 2007. <http://reep.oxfordjournals.org/cgi/content/abstract/1/1/66>.
- [40] Harman, John. "Understanding Shipboard Air Emissions Issues and Their Impact on Ship Design." Massachusetts Institute of Technology. June 2008.
- [41] Holt, Charles, et al. "Auction Design for Selling CO₂ Emission Allowances Under the Regional Greenhouse Gas Initiative." October 2007. http://www.rggi.org/docs/rggi_auction_final.pdf.
- [42] International Carbon Action Partnership. <http://www.icapcarbonaction.com/>.
- [43] International Civil Aviation Organization Air Transport Bureau (ATB). "Environmental (ENV) Unit Emissions Trading System." <http://www.icao.int/env/EmissionsTrading.htm>
- [44] Palomares, Miguel. "IMO Takes on the Environmental Challenge." *Surveyor*. Fall 2008.
- [45] The Port of Göteborg. <http://www.portgot.se/>.
- [46] The Port of Long Beach. Your Environmentally Friendly Port. <http://www.polb.com/>.
- [47] The Port of Los Angeles: America's Port. <http://www.portoflosangeles.org/>.
- [48] Rock, Nicholas J. "Shipping & the EU ETS: How will it affect you and what can you do about it?" Presented: NPDES VGP & EU Emissions Trading Seminar. February 2009.
- [49] Tongue, David. "Greenhouse Gas Emissions; Developments at IMO." International Chamber of Shipping. Presented: European Dredging Association Workshop. November 2008.
- [50] Swahn, Henrik. "Environmentally differentiated fairway charges in practice – the Swedish experience." Imprint-Europe. May 2002.
- [51] Swahn, Henrik. "Environmentally Differentiated Fairway Charges in Sweden." Swedish Maritime Administration – Department for Maritime Policy and Public Affairs. Presented: February 2006.
- [52] The Swedish Maritime Administration. http://www.sjofartsverket.se/default____603.aspx.
- [53] Vagslid, Eivind S. "International Shipping and Sustainable Development – IMO Activities on Reduction of Emissions from Ships." Marine Environment Division; IMO.
- [54] The World Bank Carbon Finance Unit. <http://carbonfinance.org/>.

