Strategies to Reduce Air Pollution in Shipping Industry*

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Contents

Abstract

Pollution emissions from international ocean-going vessels have a significant impact on public health and global climate changes. The purpose of this paper is to review the status of pollution mitigation measures implemented to date in shipping sector. Emissions control options for ocean going vessels can be classified in three broad categories: technological improvement, operational changes and market-based strategies. In addition, shipping companies have also emphasized environmental policy for the purpose of achieving corporate social responsibility and eco-efficiency. The policy implications of this paper are as follows. First, public awareness of the importance and emergency of environment in shipping industry should be required. Second, it need to investigate the actual conditions of environmental pollution from ship and port area and develop environmental evaluation scheme. Third, integrated approach is more useful method to mitigate air pollution in shipping sector. Finally, stakeholders' collaboration is a key factor for the successful environmental prevention in shipping industry.

Key Words : Air Pollution, Global Warming, Market-based Strategies

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I. Introduction

In the age of 'just in time' logistics and global supply chains, the fast and efficient movement of goods is an economic imperative. Ocean-borne commerce has been steadily increasing through the last two decades and is expected to continue to play a significant role in the globalized world economy. Expected growth in ship traffic will add significantly to local air quality problems and global climate-change risks unless ship emissions are further controlled. To date, improvements in ship environmental performance have not proceeded at the same pace as the increase in shipping activity and ship missions remain largely unregulated.

Local and regional air quality problems associated with ship emissions, especially in coastal areas, are a concern because of their public health impacts and greenhouse gas emission. Exposure to air pollution is associated with a host of health risks including premature death, cancer, heart and respiratory diseases.

Port communities are additionally burdened by their proximity to these facilities. Especially, air pollution emitted from port-related activities adversely affect the health of port workers, as well as residents of nearby port area, and contribute significantly to regional air pollution problems. Because their air pollutant emissions remain comparatively unregulated, ships and port facilities are now among the world's most polluting combustion sources per ton of fuel consumed.[1)]

Currently, international shipping and port industry has adopted new technologies such as improvement of fuel quality and ship engine technology as well as operation changes at port in order to reduce the air pollution from ship and other transport modes.

However, relative to other sources, controlling emissions from commercial marine vessels represents a significant political and legal challenge. Indeed, ships operate largely outside of national boundaries and are subject to oversight by the International Maritime Organization(IMO). The IMO has not demonstrated a willingness to establish requirements based on the best

1) Corbett et al. (1999), p.3457.

available technologies and fuels. Instead, its actions have served to codify technologies already largely adopted by the industry as a result of market forces.

The main purpose of the paper is to examine emission reduction strategies for the shipping and port sectors that will result in significant environment and public health benefits.

The paper consists of as follows: Chapter II reviews the current status of air pollution from ocean going vessels. Chapter III analyzes local, regional, and international regulation program for air pollution from ship. In Chapter IV, emission reduction strategies in shipping and port sector are suggested based on technological, operational, and market-based approach and also major players' effort for reducing air pollution are examined. The paper concludes in Chapter V with recommendations for policymakers and other stakeholders.

II. Air Pollution in Shipping Industry

1. Major sources of air pollution from shipping industry

Promoting maritime traffic safety, while protecting the ocean environment, are important concerns in global maritime industry.

Because more than 50% of a ship's operating expense is generally the cost of fuel oil, most of the world's ship operators use degraded residue heavy fuel oil in marine power plants, for its advantages in fuel economy. These degraded heavy oils, however, contain high levels of asphalt, carbon residues, sulfur and metallic compounds, as well as having properties of high viscosity (up to 700 cst), low cetane numbers and low volatility. During the burning process in marine diesel engines, boilers, and incinerators, these fuels can produce significant amounts of black smoke, particulate matter(PM), nitrogen oxides(NOx), unburned hydrocarbons(UHC), sulfur oxides(SOx), carbon monoxide(CO), carbon dioxide(CO_2), etc. These pollutants, which may deplete the ozone layer, enhance the green-house effect, and produce acid rain are detrimental to the health of living beings and have attracted a great deal of public concern.[2)]

And air pollution and health impacts from port operation are also very serious. The diesel engines at ports, which power ships, trucks, trains, and cargo-handling equipment, create vast amounts of air pollution that affect the health of workers and people living in nearby communities and contribute significantly to regional air pollution. More than 30 human epidemiological studies have found that diesel exhaust increases cancer risks, and a 2000 California study found that diesel exhaust is responsible for 70 percent of the cancer risk from air pollution.[3)] Major air pollutants from diesel engines at ports that can affect human health include PM, volatile organic compounds(VOCs), NOx, and SOx. The health effects of pollution from ports may include asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature death. In children, these pollutants have been linked with asthma and bronchitis, and high levels of the pollutants have been associated with increases in school absenteeism and emergency room visits.[4)] In fact, numerous studies have shown that children living near busy diesel trucking routes are more likely to suffer from decreased lung function, wheezing, bronchitis, and allergies. World major ports operate virtually close to residential neighborhoods, schools, and playgrounds. Due to close proximity to ports, nearby communities face extraordinarily high health risks from associated air pollution. Many of these areas are low income communities of color, a fact that raises environmental justice concerns.

2. Emission from Ocean-going vessel

Corbett & Fishbeck first developed globally emission inventory for ocean going ship and found that ocean-going ships are major contributors to global emissions of nitrogen and sulfur, and, to a lesser extent, to global emissions of CO_2, PM, hydrocarbons(HCs), and CO. They insisted that approximately 80 percent of the worldwide fleet is either harbored (55 percent of the time) or near a coast (25 percent of the time).[5)] This means most ships spend only

2) Bin L. and Cheung-Yuan L., (2006), p.220.
3) CARB(2000), NRDC(2004), pp. 1-7.
4) For more detail information on health effects of air pollution, see Bailey et al(2004, pp. 752-756.
5) Corbett and Fishbeck (1998).

about 20 percent of the time at sea and far from land.[6)] It also means that most ship emissions occur near enough to land to influence not only local air quality in coastal and harbor areas but also soils, rivers, and lakes in those areas. Studies making use of geographic marine activity data have estimated that about 70–80 percent of all ship emissions occur within 400 km (248 miles) of land.[7)] The vast majority (85 percent) of ship emissions occur in the northern hemisphere. The most affected coasts are in the Northern Hemisphere: the North Atlantic and the Pacific Rim.

IMO(2000) estimated CO_2, NOx, and SOx emission, which were based on an estimate of marine bunker fuel consumption and a statistical model and found that ocean-going vessels accounted for about 1.8 percent of global CO_2 emissions in 1996. Corbett and Koehler(2003) and Eyring et al.(2005) have produced substantially higher estimates of emissions from international maritime vessels. They found that international marine vessels account for about 30 percent of global NOx emissions from all sources and 9 percent of global SOx emissions. Table 1 summarized previous studies on fuel consumption, estimated emission from international ships.

<Table 1> Fuel consumption, Emission from International ship

(Over 100GT, M. Metric Ton)

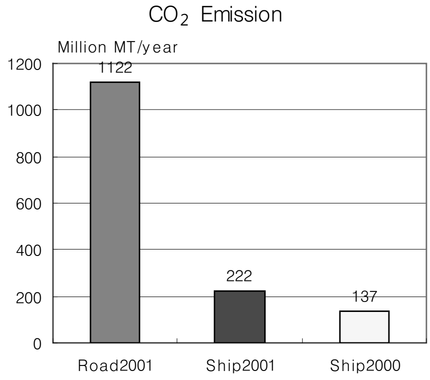
Source	Year of Publication	Fuel Consumption	NOx	SOx	PM	CO_2	Inventory Year
Eyring et al	2005	280	21.4(29%)	12(9%)	1.7	813(3%)	2001
Corbett & Koehler	2003	289	22.6(31%)	13(9%)	1.6	912(3%)	2001
Endresen et al	2003	158	12(17%)	6.8(5%)	0.9	501(2%)	2000
IMO	2000	120~147	10(14%)	5(4%)	-	419(1.5%)	1996

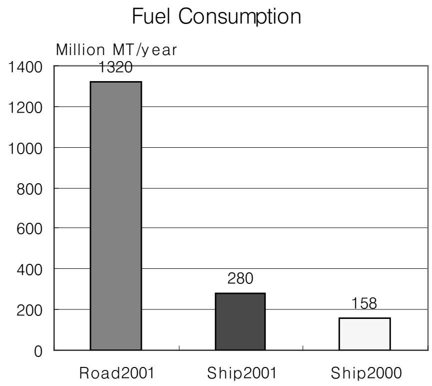
Figure 4 and Figure 5 show comparison between the emission from marine sources and the on-road transportation sector. Figure 4 suggests that global fuel consumption and CO_2 emissions from marine sources are about 12– 21 percent the contribution from on-road transportation sources.

6) Corbett et al.(1999), p. 3462.

7) IMO (2000) and Corbett et al.(1999).

<Figure 1> Estimated Global CO_2 Emission and Fuel Consumption for Ships and Road Vehicle(2001)

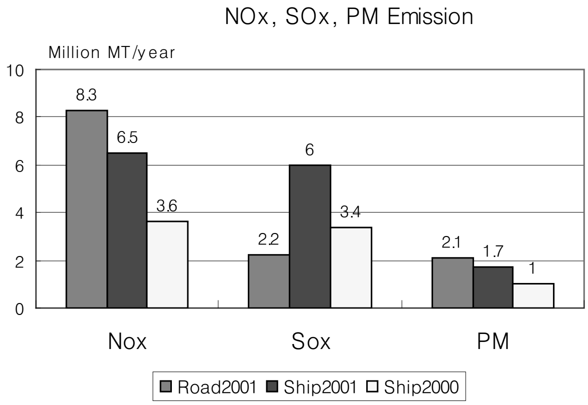




Source : Eyring et al (2005a); Endreesen et al (2003)

However, according to Figure 2, criteria pollutant levels are on par with, or even greater than, emissions from all on-road vehicles. Emissions of SOx from international ships exceeded SOx emissions from on-road sources by a factor of 1.6 to 2.7. NOx and PM emissions from ships are lower than the estimated emissions from all on-road vehicles (44 to 78% for NOx and 48 to 81% for PM). Although the emission estimates from Endresen et al.[8] are approximately a factor of two lower than those from Eyring et al.,[9] both sets of results support the finding that ship emissions are significant compared to emissions from on-road sources.

<Figure 2> Estimated Global NOx, SOx, PM Emission Ships and Road Vehicle



Source : Eyring et al (2005); Endreesen et al (2003)

8) Endresen et al. (2003).

9) Eyring et al. (2005).

Recently, ICCT(2007) forecasted the future emission from international shipping through 2050. According to ICCT, if current trends continue, the ship contribution as a percent of global emissions in 2050 is expected to rise to more than 30 percent for NOx, 18 percent for SOx, and 3 percent for CO_2. Total ship emissions of fine particles matters are also estimated to more than double in that period. The sector's share of SOx emissions, in particular, is expected to grow significantly over the analysis period, primarily due to continued progress in reducing land-based sulfur emissions from coal-fired power plants and on-road vehicles. Similarly, progress in regulating land-based NOx emissions means that the shipping contribution as a share of global emissions of this pollutant is also projected to grow, albeit less dramatically than in the case of SOx. The trend is different for CO_2 simply because carbon emissions from all other sources are not yet being significantly regulated on a global basis. The air quality impacts of projected growth in ship emissions of NOx, SOx, and PM are likely to be especially significant in the Pacific Rim and North Atlantic regions due to the concentration of shipping activities in those regions.

III. International Measures against Air Pollution from Ship

The International Maritime Organization(IMO) is responsible for drafting various international conventions related to maritime affairs, with regulations covering navigation, marine rescue, and ships' structural and equipment requirements. There are currently more than 150 countries belonging to the IMO, which is the most powerful international organization in the field of ocean shipping. The objectives of the IMO include sustaining safety in sea transportation, promoting navigational efficiency, and protecting the ocean environment. The Marine Environment Pollution Committee (MEPC), which is a sub-organization of the IMO, is specifically responsible for drawing up relevant regulations to prevent ships from polluting the ocean and the atmosphere.

With the rapid development of international commerce, the number of global shipping vessels has also increased. Pollution from these ships is of great concern, particularly, oil spills due to casualties at sea. To address this pollution, the IMO amended the 1973 International Convention for the Prevention of Pollution from Ships protocol in 1978, which is referred to as MARPOL 73/78. This protocol regulates the draining standards for used oil, sewage, and waste materials. Air polluting exhaust, from marine power plants, has also become a cause for concern within the international community in recent years.

The MEPC began examining ships' air pollution in 1988. Consequently, a new air pollution addendum to MARPOL 73/78, which is now referred to as Regulations for the Prevention of Air Pollution from Ships or MARPOL 73/78 Annex VI, was adopted in 1997, which entered into force on May 2005. These regulations to prevent ships' air pollution include the following: (1) emission standards for NOx according to the power output of marine diesel engines and required installation of exhaust gas cleaning systems to reduce NOx emissions; (2) limits in sulfur content of fuel oil used in ships to reduce SOx emissions and requirements for exhaust gas cleaning systems or technologies to limit SOx emissions to 6.0 g SOx/kWh or less; (3) provision for vapor collection systems, or other vapor emission control systems to reduce the emissions of VOCs; (4) Requirement for shipboard incinerators; (5) restricted use of CFC refrigerants, Halon, and other ozone-depleting substances.

Recently, MEPC adopted amendments to the MARPOL Annex VI regulations to reduce harmful emissions from ships even further, when it met for its 58th session at IMO's London headquarters.[10] The main changes to MARPOL Annex VI will see a progressive reduction in SOx emissions from ships, with the global sulphur cap reduced initially to 3.50% (from the current 4.50%), effective from 1 January 2012; then progressively to 0.50 %, effective from 1 January 2020, subject to a feasibility review to be completed no later than 2018. The limits applicable in Sulphur Emission Control Areas (SECAs) will be reduced to 1.00%, beginning on 1 July 2010 (from the current 1.50 %); being further reduced to 0.10 %, effective from 1 January 2015. Progressive reductions in NOx emissions from marine engines were also agreed, with the most stringent controls on so-called 'Tier III' engines, i.e. those installed on ships constructed on or after 1 January 2016, opera-

10) MEPC.176(58) Amendments to the Annex of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (Revised MARPOL Annex VI)

ting in Emission Control Areas.

However, there are some limitations in IMO's regulation for preventing air pollution from ship. First, the MARPOL Annex VI standards set limits for NOx emissions that vary with engine speed. The IMO characterized the NOx standards as a 30 percent reduction from current levels, but the U.S. EPA more recently determined that the standards would reduce NOx levels by 20 percent. No standards have been set for particles, hydrocarbon, or carbon monoxide emissions. Second, Annex VI sets a global cap on fuel sulfur at 3.5 percent. The average sulfur content of fuels currently used in ships is 2.7 percent. Consequently the benefits of the IMO fuel program are expected to be limited. Third, existing IMO's regulation standards for NOx emissions and fuel sulfur content merely codify existing industry practices. It is expected that a significant portion if not all of these reductions would have been obtained without regulation. Thus the costs and benefits associated with current IMO regulations have been characterized as 'negligible' by the U.S. EPA compared to a business-as-usual baseline.[11)]

IV. Emission Mitigation Strategies in Shipping Industry

1. Industry Perspectives

Emissions control options for marine vessels can generally be classified in three broad categories. First of all, technology improvements can reduce both local and global emissions by replacing or upgrading older, less-efficient or higher-polluting engines with more efficient and lower-emitting propulsion systems. Second, operational changes reduce local emissions by modifying how vessels operate while entering and docking in the harbor. Although the fraction of global ship emissions that occurs during in port operations is modest compared to at sea emissions (with the exception of CO emissions), in-port emissions—because they generally occur near populated areas—are likely to have a disproportionate impact on local emission inventories and public health risks. Third, market-based programs, such as variable port fees and emissions trading programs, can spur both operational and technology changes if they are well designed and implemented.

11) US EPA (2003), pp. 56-75.

1) Technological Strategies

The combination of low fuel quality and limited pollution control requirements for engines and vessels has led to the marine sector's poor environmental performance with respect to air emissions. A variety of strategies for reducing ship emissions—from the use of lower sulfur fuel to engine improvements and exhaust after-treatment—have been demonstrated in a full range of ocean-going vessel types. These strategies generally focus on NOx or SOx emissions because they are currently the only internationally regulated ship air pollutants.

NOx emission reductions can be obtained by engine upgrades aimed at reducing combustion temperatures, for example by adding water at different stages of the combustion process or re-circulating exhaust gas. NOx reductions can also be obtained by using exhaust after-treatment such as selective catalytic reduction (SCR).[12)] SOx emission reduction strategies primarily consist of switching to lower sulfur marine fuels[13)] and use of seawater scrubbing.[14)] These strategies can also provide substantial PM emission reductions.

While docked at port, vessels use their auxiliary engines and sometimes their main engines to provide heating, cooling, and electricity, as well as loading and unloading. Emissions generated at dock (referred to as hotelling emissions) often contribute significantly to local emission inventories and to potential health risks from human exposure to harmful pollutants. To date, three main strategies have been implemented or proposed to reduce local emissions: use of lower sulfur alternative fuels in auxiliary engines, electrification with use of a shore-based power supply, and shore-based emission treatment. The use of lower sulfur marine diesel oil or pure distillate marine gas oil (MGO) can provide significant SOx and PM reductions compared to using heavy fuel oil.

Shore-side power (known as cold ironing) is delivered by plugging the ship in to a land based electric supply. Cold ironing eliminates all hotelling emissions from the ship at port. With respect to Cold Ironing, following facts should be considered.

Unless electricity is generated from zero emission sources such as solar or wind

12) Selective catalytic reduction (SCR) is a means of converting NOx with the aid of a catalyst into N_2, and H_2O. A reducing agent, typically ammonia or urea, is added to a stream of exhaust gas and is absorbed onto a catalyst.

13) The use of fuel oil with 1.5 percent (0.5 percent) sulfur content would reduce global SOx emissions from ships by over 40 percent (80 percent).

14) This after-treatment technology takes advantage of seawater's ability to absorb SO_2. As the exhaust passes through cascading seawater in a scrubbing tower, it is scrubbed of a large fraction of SO_2 and a smaller fraction of PM.

power, emissions are only displaced to the power generating facility. And implementing shore-side power not only requires building the landside power delivery infrastructure but also retrofitting ships so they can be connected. Such retrofits are often more complicated than building new ships designed for cold ironing. Also the size and proximity of power supplies to the port is a key factor in determining the required shore-side power delivery infrastructure.[15)]

A shore-side emission treatment system is demonstrated as an alternative to shore-side power at the Port of Long Beach. This system is connected to the ship exhaust stack and the exhaust is funneled to a combined SCR and scrubber system installed on a barge or on the dock. The system is expected to reduce NOx emissions by 95 percent and SOx and PM emissions by 99 percent.[16)]

2) Operational Strategies

Most operational changes for emission reduction generally focus on measures taken while ships are at the port, while technology improvements provide emission reductions under cruising and/or hotelling conditions. The potential emission reductions from operational changes are very important as they can significantly contribute to improving local air quality and reducing the exposure of nearby populations to harmful pollutants.

Port operators require specific control technologies such as cold ironing or the use of lower sulfur fuels and other emission-control technologies when ships are operated under port jurisdiction. It should be noted that there is often intense competition between ports to capture as much of the cargo as their capacity permits. As a result, local ports are frequently reluctant to implement local environmental requirements out of concern that this will put them at a competitive disadvantage relative to other nearby ports. Despite competitiveness concerns and the absence of national or international consensus on controlling ship emissions, several ports have adopted local pollution control requirements including operational changes. For example, a voluntary speed–reduction program in effect in the San Pedro Bay (ports of Los Angeles and Long Beach, California) is estimated to be reducing NOx emissions by as much as 4–8 percent.[17)] Speed

15) CARB (2005), pp. 9-10.
16) Port of Long Beach (2006), p. 1.
17) CARB (2002), pp. 15-18.

reductions while approaching shore and navigating within ports reduces ship-engine NOx emissions by reducing the load on the vessel's main engines. And California has adopted fuel quality standards for auxiliary engines. Starting in 2007, marine gas oil or marine diesel oil with a sulfur content limited to 0.5 percent or less must be used in auxiliary engines operated within 24 nautical miles (44.5 kilometers) of the state's coastline. This criterion will reinforce to 0.1 percent sulfur standard from 2010.

3) Market-based Strategies

In addition to regulatory measures, market-based strategies should be considered when reviewing policy options to address environmental impacts from the shipping sector. Emission reduction programs that are either based on market incentives or structured to allow variable industry responses generally allow shipping companies to tailor compliance actions to their specific circumstances. Such approaches can produce the optimum balance between technology and operational controls. Market-based programs can be implemented locally—for example, by imposing variable fees designed to reward low-emissions and/or high-efficiency vessels (and conversely penalize high-emissions and/or low-efficiency vessels)—or internationally, through an emissions cap-and-trade system.

One of the successful market-based measures to reduce air pollution from ship is voluntary differentiation in port dues. This approach has introduced in Sweden since 1998-which is called Environmentally Differentiated Fairway Dues Program- where less polluting ships are entitled to a reduction in fairway as well as port dues in participating ports. This voluntary program was the result of an agreement between the Swedish Shipowner's Association, the Swedish Port and Stevedore Association, and the Swedish Maritime Administration(SMA), which is tasked with administering the program. The program's original goal was to reduce NOx and SOx emissions from ships traveling in Swedish waters by 75 percent over ten years.

Under the program, baseline dues are levied proportional to each vessel's gross tonnage(Swedish Kronor/GRT). Individual vessels can then qualify for reductions from the baseline dues based on their emissions performance. Since the program was designed to be revenue neutral, baseline fairway dues were first increased so as to create room for fee reductions without an overall loss of revenues. Fee reductions for NOx performance are assessed based on vessel emissions in grams per kilowatt-hour (g/kWh) as measured by an independent body. Fee reductions for SOx performance are assessed based on the sulfur content of the fuel used. NOx and SOx performance is certified for 3 years and periodically verified. The maximum NOx emission and fuel sulfur categories were lowered in 2005 to reflect improvements in NOx control technology and the availability of lower sulfur fuel. Currently, the maximum dues reduction is offered to ships that emit 0.5 g/kWh of NOx or less and that use fuel with sulfur content less than or equal to 0.2 percent. In addition to the SMA program for fairway dues, 30 of the 52 ports in Sweden impose environmentally differentiated port dues. These programs vary widely amongst individual ports and, because of the competition among ports, typically offer fee reductions that are smaller than the fairway dues program. The main results of this program are as follows. In 2005, 1,127 ships, accounting for 80 percent of the ferry tonnage and 50 percent of the cargo tonnage calling on Swedish ports, were participating in sulfur portion of the program.[18)] Over the program's eight years of implementation, a total of 44 vessels were outfitted with NOx control technologies. The majority of vessels in the program have opted for installing SCR on their main engines to achieve NOx reductions; as a result, average NOx reductions totaled 87 percent. Among the lessons learned early in the implementation of the Swedish program was the need for additional incentives to encourage the installation of NOx control technologies. Unlike switching to lower sulfur fuel, reducing NOx emissions requires additional capital investments. To overcome this hurdle, the program offered to cover up to 40 percent of the capital cost of low-NOx retrofit technology for equipment installed before January 2000 and 30 percent for projects completed before January 2003. The Swedish program can have a significant impact on local emissions but their impact on global emissions is generally small since only the vessels calling at a few specific ports are affected. Nevertheless, they serve to demonstrate the viability of larger scale programs implemented regionally, nationally, or even internationally. If

18) Kågeson (2006).

a system of fees was adopted such that operators would be subject to similar incentives or penalties throughout a region or in all their ports of call, they will have little alternative but to 'price' the impact of such fees into their overall technology investment cost. The larger the geographic scope of a control program, the greater the incentive to consider investments in emission reduction strategies.

Another market-based mechanism for addressing greenhouse gas emissions is a cap and trade system. Cap and trade system(or emission trading) is an administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. A central authority, usually a government or international body, sets a limit or cap on the amount of a pollutant that can be emitted. Companies or other groups are issued emission permits and are required to hold an equivalent number of allowances(or credits) which represent the right to emit a specific amount. The total amount of allowances and credits cannot exceed the cap, limiting total emissions to that level. Companies that need to increase their emission allowance must buy credits from those who pollute less. The transfer of allowances is referred to as a trade. In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions by more than was needed. Thus, in theory, those that can easily reduce emissions most cheaply will do so, achieving the pollution reduction at the lowest possible cost to society.

Under such a program, specific global emissions caps would be set for the shipping industry either by the IMO or by states. These caps could decline over time as ecological considerations dictate and as new technology options become available for reducing emissions. Many issues would need to be resolved prior to the implementation of a cap and trade system, including the geographic scope (i.e., regional, national, or international) and coverage of the program (i.e., which pollutants and how much of the shipping fleet would be included); whether emission reduction credits from off-sector sources would be allowed; what baseline would be used to measure reductions; and how allowances would be allocated. The net effect of the policy should be to induce vessel operators to implement the most cost-effective fleet-wide emission reductions. Cap and trade approaches have become popular in a variety of regulatory contexts over the

<Table 2> Summary of Emission Mitigation Options for Ships

Measure Type	Measure	Description	Examples
Technological Strategies	Lower Sulfur Fuel	● Marine residual or bunker with sulfur content at 1.5% or below (44% SOx reduction, 18% PM reduction) ● Marine distillate and gas oil with sulfur content at 0.1% or below (>90% SOx reduction, >80% PM reduction)	● EU (and IMO) Sulfur Emission Control Area: Baltic Sea (2006), English Channel and North Sea (2007) ● San Pedro Harbor Maersk voluntary agreement (0.2% sulfur fuel, 2006) -California auxiliary engine rule (2007)
	Selective Catalytic Reduction (SCR)	● Exhaust after-treatment technology providing over 90% reduction in NOx. PM, CO, and HC reduction can be obtained when SCR is combined with a PM filter and an oxidation catalyst	● Units in service starting in early 1990's in applications ranging from ferry, cruise ship, to roll-on/ roll-off vessels
Operational Strategies	Vessel Speed Reduction	● Speed within harbor is reduced to reduce engine load and NOx production (4%–8% reduction)	● Voluntary program in the Los Angeles/Long Beach harbor since 2001
	Shore-side Power	● Land based power for docked ships (100% reduction in at-port emissions)	● Facilities operating in the Baltic and North Seas, Juneau (Alaska), Port of Los Angeles
Market-based Strategies	Environmentally Differentiated Fee	● Fee reductions based on vessel environmental performance. Emissions benefits depend on level of participation and implemented technologies.	● Voluntary Environ-mentally Differentiated Fairway Dues Program in Sweden since 1998
	Cap and Trade System	● a government or regulatory body first sets a limit or 'cap' on the amount of environmental degradation or pollution permitted in a given area and then allows firms or individuals to trade permits or credits in order to meet the cap.	

last decade because they provide industry with flexibility and allow the market to determine where and how emission reductions can be achieved most cost-effectively. Vessel operators that can curtail emissions less expensively can sell excess emission credits or allowances to vessel operators that would otherwise face higher costs to implement reductions.

A cap-and-trade approach in the shipping context may have some disadvantages. The administrative difficulty of implementing such a program on a global basis may be substantial. And this program is more suited to pollutants such as CO_2 (which have equivalent environmental impacts no matter where they are emitted) than to non-CO_2 GHG emissions, such as diesel PM, that are also associated with localized public health or environmental impacts and for which "hot spots" of concentrated emissions are a concern.[19)]

19) Harrington et al.(2004), pp. 17-19.

2. Shipping Company's Perspectives

1) Maersk

Through an extensive strategy process in 2008, A.P. Moller-Maersk Group developed a comprehensive environmental strategy, which named 'Eco-efficiency', to minimize its environmental footprint in the future. Maersk's approach to limiting the environmental impact is that not only does its duty to society in general, but also environmental consciousness also creates business opportunities. In other words, reducing fuel consumption is directly connected to limiting CO_2 and other emissions. Some of the options contributing to reducing emissions in the strategies are as follows:[20] First, Maersk introduced Waste Heat Recovery System on its vessels results in considerable reductions in CO_2 emissions since 1988. By adding a boiler to the vessel's funnel Maersk is able to utilize the exhaust heat to generate steam, which can be used for propulsion. The system contains the potential to reduce fuel consumption and CO_2 emissions by up to 10% and should result in saving half a million tons CO_2 per year when 58 of its existing and ordered container vessels have the system installed. This system was reinforced in 2005 when Maersk built the new large PS-class container vessels like Emma Maersk at Odense Steel Shipyard. They all have Waste Heat Recovery. Maersk has attained the position as the only shipping liner in the world to install the system on large scale. Second, Maersk developed optimized voyage planning program to save fuel and reduce emissions. The Voyage Efficiency System (VES), a Maersk's voyage planning program, is used on all large ships (and chartered ships) to identify the most fuel efficient route and a 'just in time' steady running strategy is applied to keep the engine load at a minimum. Third, Maersk tried to reduce air emission through efficient refrigerated containers. The QUEST(Quality and Energy efficiency in Storage and Transport) program is a joint development project sponsored by Dutch Government. QUEST is a software solution that installs software in containers to reduce energy consumption for cooling in containers. It enables to cut the energy consumption used for cooling by up to 50% without having an impact on the quality of its refrigeration solution. At the end of 2008, 69% of Maersk Line and Safmarine's reefer fleet was equipped with Quest software, generating CO_2 savings equivalent to 260,000 ton

20) PREPARING FOR THE FUTURE, The A.P. Moller - Maersk Group's Health, Safety, Security and Environment Report 2008, 2009.5.

per year. Fourth, Maersk Line began a pilot test to use clean fuels near California ports in 2006. The California Fuel Switch Initiative reduces SOx significantly by switching from conventional bunker fuel with relatively high sulphur content to low-sulphur distillate fuel, containing less than 0.2%. This exercise is carried out on the main and auxiliary engines of the vessels 24 miles from port, while docked and until 24 miles out on departing journeys. Results from this pilot program show substantial reductions in key pollutants: 87% annual reduction in PM, 95% reduction in SOx, and 12% reduction in NOx. Since then, the program has been implemented on all vessels sailing to and from California. In addition, A.P. Moller - Maersk has ensured compliance with the Sulphur Emission Control Area(SECA) in the Baltic Sea, the English Channel and the North Sea. In this area, the maximum sulphur content allowed in fuel oil is 1.5%.

2) MOL

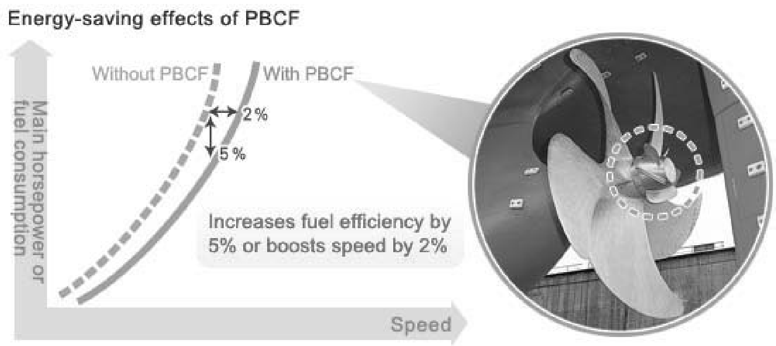
MOL developed wind/water resistance reducing design PCTCs(Pure Car and Truck Carriers) with various modifications to improve energy efficiency. The shape of conventional car carriers makes them more susceptible than other ships to wind resistance and a phenomenon called “leeway,” in which the wind pushes the vessel from the side. Naturally, that reduces fuel efficiency. MOL teamed up with Universal Shipbuilding Corp. and Osaka University to develop an innovative pure car carrier, called the Courageous Ace, in March 2003. By reducing the wind resistance from the bow with an aerodynamically rounded and bevelled bow line and having wind channels along the sides at the top of the garage deck, the vessel can maintain a straighter course than before.

<Figure 3> MOL’s Innovative PCTC : Courageous Ace and Utopia Ace

Source : MOL Homepage(www.mol.co.jp)

And the Utopia Ace, launched in July 2004, features a hyper-slim energy-saving design under the waterline, reducing resistance by 8% compared to a conventionally designed vessel. Additionally, the ventilation covers on the shipside decks feature aerodynamically rounded sides, to further cut wind resistance. Second, a ship's propeller moves the vessel by changing rotational energy into propulsion energy. Since water is twisted when the prop rotates, a vortex always occurs behind the propeller. This results in energy loss in the propulsion of the vessel. The MOL-developed Propeller Boss Cap Fins(PBCF) has the same number of fins as propeller, and is installed at the rear of the propeller hub. The PBCF is capable of enhancing propulsion efficiency by effectively breaking up the strong hub vortex. The result is a 4-5% improvement in fuel efficiency (which also reduces CO_2, NOx, and SOx emissions) at the same speed. Since development started in 1987, all types of vessels worldwide have been fitted with the PBCF system. The accumulated number of vessels ordered PBCF system topped 1,000 in January 2006.

<Figure 4> MOL's PBCF for improving ship's propulsion power



Source : MOL Homepage(www.mol.co.jp)

3) NYK

NYK has traditionally conducted its Save Bunker Campaign as a means of conserving fuel and reducing CO_2 emissions. They have renamed this campaign Save Bunker Innovation since 2008 to reflect its role as a driving force in the development and improvement of environmental technology by the NYK Group.

One of the new devices NYK use to encourage fuel savings is the FUELNAVI fuel consumption monitor. The device provides a real-time indication of fuel consumption performance measured as distance traveled per ton/day of fuel consumed. It functions the same way as a fuel consumption meter on automobile, monitoring fuel efficiency during the voyage and helping to improve it. It is also possible to measure speed, route, wind speed and direction, rudder angle, and engine rotation to analyze the impact on fuel consumption of weather and sea conditions.

Furthermore, NYK makes use of the current forecast information to monitor detailed current speed distribution within the Kuroshio Current. The Kuroshio Current, which occurred near Taiwan Strait, is one of the world's two major ocean currents and is known for its high speeds. NYK tankers exploited this current to save fuel and reduce emission from ship during sailing from Middle East to Japan. This system was confirmed to save a maximum of 9 percent in fuel consumption and CO_2 emissions compared with the use of traditional current estimate maps.

V. Conclusion

Although ocean-going vessels are considered as the most environmental-friendly transport modes, they also generate substantial quantities of greenhouse gas emissions. Pollution emissions from international ocean-going vessels already have a significant impact on air quality and public health, especially in coastal communities. Moreover, emissions from shipping sector are expected to continue to grow strongly as the global economy expands and as international trade plays an ever larger role. As progress is made in reducing emissions from land-based sources, the ship contribution as a percent of NOx, SOx, and PM inventories is likely to grow even faster than absolute emissions.

Under these circumstances, this paper reviewed the status of pollution control measures and programs implemented to date in shipping sector. Emissions control options for ocean going vessels can be classified in three categories: technological improvement, operational changes and market-based strategies.

First, as technology strategies, replacing or upgrading older engines and propulsion systems, use of low sulfur fuels, and exhaust after treatment such as selective catalytic reduction (SCR) have been shown to significantly improve the environmental performance of marine vessels. Second, as operational strategies, shore side electricity, improved fuel quality standards for auxiliary engines and voluntary speed reduction program can reduce emission from ship. Third, as a market-based strategy, Swedish voluntary differentiation program in port dues is a successful program for reducing air pollution from ship. And cap and trade system, which has not been introduced in international shipping industry, can be a good alternative for shipping company's voluntary emission control. However, it is important to note that integrated approach among these three strategies is the most effective way to reduce air pollution from ship.

In addition world major shipping companies have also emphasized environmental policy in their business activities for the purpose of achieving corporate social responsibility and eco-efficiency. Shipping companies try to appeal to their customers as an environmental-friendly firm by complying with environmental regulation. Because, as the importance of environment problem is rapidly increasing in global perspective, shippers require their goods to be transported with the least possible impact on the environment. Furthermore, shipping companies have recognized that environmental efforts could be a good solution for not only reduction of air pollution but also achievement of fuel efficiency.

The policy implications of this paper are as follows. First, public recognition on the importance and emergency of environment in shipping industry should be required. Because greater public awareness of the environmental impact of routine ship activity will undoubtedly result in added pressure to reduce emission. To this aim, government accomplish public relations and education for the environmental problems from shipping industry, the industry also need to conduct training program for all the staff to improve environment protection. Second, it needed to investigate the actual conditions of environmental pollution from ship and port area and develop environmental evaluation scheme for the persisting monitoring. For example, development of green shipping evaluation index can be a useful method for shipping companies to participate voluntarily in environment improvement as a means of ex ante economic incentives instead of ex post administrative regulation. Undoubtedly, it should be provided the support criteria for participant by using the indexation and ranking of evaluation indicator. Third, developed countries preferred to incentive-based approach for the industry's voluntary participation instead of legal regulation to mitigate air pollution in shipping and port sector. Especially, since legal regulations impede the level playing field among shipping companies, monetary incentive or penalty based on market mechanism is highly recommended in most major shipping countries. Last but not least, stakeholders' collaboration is required for successful environmental prevention in shipping and port industry. One of the common characteristics of ship emission strategies in developed countries is the collaboration between public and private sectors and across a wide set of stakeholders. Thus, best practice should be shared with shipping companies, terminal operators, local residents and government for addressing both local air quality concerns and global warming.

The limitations of this study and further researches are as follows. First, methodology for assessing the cost-effectiveness of three strategies for reducing air pollution from ship should be developed. One of the benefits of cost-effectiveness approach for regulatory development is that the resulting regulations will be based on a sound rationale, and that pertinent costs imposed by new requirements may be defended based on achievable emission deduction. Second, clean air program for port operation also should be examined. Because air pollution reduction efforts will be more effective when they are conducted both at sea and in port.*

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