Study on the Reduction of Energy Consumption and Prevention of Harmful Exhaust Emissions from International Shipping in the APEC Region

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APEC Project: Study on the Reduction of Energy Consumption and Prevention of Harmful Exhaust Emissions from International Shipping in the APEC Region

Produced by
China Waterborne Transport Research Institute
No. 8, Xitucheng Road, Haidian District, Beijing, PR China 100088

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

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Abstract

Atmospheric environment is vital to human health and sustainable economic development, and vulnerable to harmful exhaust emissions. Although air pollution from ships does not have the direct cause and effect to the environment as other maritime incidents, it causes a cumulative effect that contributes to the overall air quality problems encountered by population in many places, including APEC region. As shipping is playing an increasingly significant role to trade and commerce in the APEC region, air pollution from ships has become one of the imminent concerns for APEC member economies. Despite that shipping is an environment friendly way of carrying goods around the world, the environmental impact of shipping should also be properly addressed.

This project aims to achieve green growth and promote the development of clean and efficient transportation system in the APEC by providing solutions to member economies for optimizing fuel consumption, using clean energy and reducing harmful exhaust emissions from ships while maintaining the sound and sustainable development of shipping.

Through studying the ship SO_X and NO_X emissions scenario in the port of Incheon and the port of Ningbo, this project examines the existing regulatory, technical, operational and market-based measures addressing the air pollution from ships, and summarizes best practices and proposes recommendation for member economies to develop strategies to deal with the harmful emissions from ships and protect the environment of the entire APEC region.

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Chapter 1 Introduction

Ships emit a range of gases from their operations at seas and in port areas. The emissions produced by navigation result from the combustion of fuel in internal combustion engines. The principal pollutants from internal combustion arise from two main sources: soot associated with inefficient engine technology emitting carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_X) and particulate matter (PM); and sulfur-rich fuels emitting carbon dioxide (CO_2), sulfur dioxide (SO_2), heavy metals and PM. (EEA, 2009)These pollutants can be divided into local, regional and global effects. NO_X, SO_2 and PM are major concerns in local and regional areas because of their environmental impact, such as acid rain and photochemical smog and more importantly critical damage to human health causing serious respiratory and cardiovascular problems, and asthma. (Cullinane and Edwards, 2010)CO_2 is global concern as the dominant greenhouse gas (GHG) due to global warming and climate change issues.

Many countries, regions and international organizations have adopted more stringent regulations to address air-polluting gases from ships. To reduce the GHG from ships on a global scale, the Kyoto Protocol delegated the obligation of reducing the emissions of GHG shipping to the International Maritime Organization (IMO) in 1998(United Nations, 1998). Since then, the IMO has made major efforts to develop a range of measures to reduce GHG emissions. Technical and operational measures were adopted by the IMO and market-based measures are currently under discussion (Miola et al., 2011). In principle, these measures focus on the emission activities of vessels at sea. Along this line, many researchers have addressed the question of how GHG emissions from maritime transportation can be reduced (Cariou, 2011; Cariou and Cheaitou, 2012; Chang and Wang, 2012; Corbett et al., 2009; de Marucci, 2012; Kim et al., 2012; Liao et al., 2009; Miola et al., 2011; Psaraftis and Kontovas, 2010; Uriondo et al., 2011; Villalba and Gemechu, 2011) On the other hand, to regulate SO_2, NO_X, and PM for environmental protection on a local and regional level, northern and western European countries designated the Baltic Sea and North Sea as an Emission Control Area (ECA), which came into force on May 19th, 2006 and November 22nd, 2007, respectively. One year after the ECAs in Europe, the IMO adopted a set of amendments to Annex VI of the MARPOL Convention to limit NO_X and SO_X emissions from ships. Furthermore, the North American ECA including most of the US and Canadian coast came into force in 2011. US government plans to expand the ECA into Puerto Rico and the US Virgin Islands. Consequently, ships navigating in these ECAs should use marine fuels with a maximum of 1% sulfur by weight. The sulfur content limit in the ECAs will be lowered to 0.1% on January 1st, 2015. In addition, ships navigating in all other international waters have touse marine fuels with a 3.5% sulfur content as of 2012 (cut by 1% from previous 4.5%) and the limit will be lowered to 0.5% as of 2020 according to IMO regulations. (Madsen and Olsson, 2012)

While noxious gases (NG) - SO_2, NO_X and PM- have been more regulated stringently in Europe and North America by designating the ECAs, NG are not considered a major concern in Asia and other continents because these continents have not designated any ECAs. An assessment of the emissions of NG by ships to consider the designation of ECA(s) is of paramount importance, particularly in Asia because this region has most of the top ranking ports in the world. Therefore, the maritime traffic intensity is highest. Moreover, the region is most densely populated along the coastlines in the world and so the impacts of NG on their environment and coastal residents must be as high as, or higher than those in Europe and North America. On the other hand, no studies have been carried out in this region regarding the assessment of NG in considering ECAs in the literature. Furthermore, the extant studies on the assessment of NG in the ECAs or non-ECA sea areas in the world were mostly macro-level analysis using a top-down approach (Browning et al., 2012; Jalkanen et al., 2013; Kotchenruther, 2013; Ma et al., 2012; Schrooten et al., 2009; Streets et al., 2000; Tran and Mölders, 2012; Tzannatos, 2010; Wang and Corbett, 2007)or a very small sample-based bottom-up approach (Cooper, 2003; Moldanová et al., 2009; Winnes and Fridell, 2010).Europe's emission inventory guidebook (EEA, 2009) recommends that ship movement-based methodology, known as the Tier 3 methodology, should be used to capture more accurate inventory when detailed ship movement data and technical information on ships (engine size, power installed or fuel use and hours in different activities) are available. A literature review showed that no studies had used this Tier 3 method for capturing NG emissions.

This report intends to conduct a study on the prevention and reduction of harmful exhaust emissions (SO_X, NO_X and PM) from international shipping in the APEC region for the protection of marine and atmospheric environment and the reduction of energy consumption in the APEC community. More specifically it attempts to develop a robust methodology in assessing the emissions of NG in the most detailed micro-level using the data of all vessels. The developed methodology is applied to two case study ports: one in Korea and the other in China. First of all, vessels data that used the Port of Incheon (POI) in Korea in 2012and the Port of Ningbo (PON) in China are collected. The POI is the gateway port to the capital region of Korea including Metropolitan Seoul, Incheon and Kyounggi Province with a population of 24 million comprising 49% of the national population and handles more than 150 million tons of cargo and fast growing container cargo in recent years amounting to more than 2 million TEUs. The POI plans to expand its container terminals massively in the near future to be on par with its counterpart container ports in China across the Yellow Sea, such as Qingdao, Dalian and Tianjin. The POI area can be considered as a most likely potential ECA in Korea in the future because of its heavy maritime traffic and densely populated coastal areas. PON is well situated in the middle of China's coastline, at the T-shaped joining point of China's coastline and the Yangtze River. It is one of the busiest deep-water transshipment ports in China. It enjoys its unique natural conditions with convenient traffic reaching in all directions. Outwardly the port links East Asia and the whole round-the-Pacific region. Inwardly it connects China's coastal ports and covers directly the whole East China and the economically developed Yangtze River Delta by river-sea through transport via the Yangtze River and the Grand Canal. The population of Yangtze River Delta is 159 million, more than 1/10 of the national population. In 2012, approximate 445 million tons of cargo were handled in Ningbo port, increased by 15.3%. The container throughput of Ningbo in 2012 is 15.7 million TEUs, increased by 8%, ranked 3th in China and 6th in the world. Ningbo now has more than 300 berths and 67 of them are deep-water berths which are capable to serve vessel with more than 10,000 dwt. In the next 5 years, 31 new deep-water berths including 9 container berths are in the construction plan of Ningbo port. The green development has been included in the future strategy plan of Ningbo port. Now, Ningbo has implemented program like encouraging truck driver to use LNG instead of the gasoline. In the future, the PON could be the most likely potential ECA in China.

Using the two sample port cases, this study estimates the NG emissions based on the type of vessel and the movement of vessels from port arrival (anchoring and maneuvering to approach a berth) to docking, cargo handling, and departure. The geographical scope of this study was 25 nautical miles from the main dock areas of the POI and PON because this distance is the vessel traffic control area of the POI and PON. Furthermore, the emissions at this distance directly affect the coastal residents according to environmental experts. Vessels entering the POI typically pass through two lock gates to approach their assigned berths at the main port due to the 9 m tidal difference. This report captures the vessel's maneuvering activities after its port entry, including its passage through lock gates in POI, docking for cargo handling and departing for next port of call.

Chapter 2 Overview of Emissions by Shipping

The world total shipping fleet is composed of 55% slow-speed diesel, 40% medium speed diesel and 5% other engine types. The vessels used for transportation purpose represents 69 % of world nitrogen emissions and 73 % of sulphur emissions. The remaining vessels are fishing, service craft, military and other types, contributing the remaining portion of 31% for nitrogen and 27 % for sulphur (Corbett &Fischbeck, 1997).

Various studies on estimating emissions of NG from shipping have been conducted resulting in varying results over time. Of the numerous estimates, most frequently cited and also seemingly reliable results are the one done by (Corbett &Fischbeck, 1997). Their estimates of NO_X and SO_X per annum equate to 10.12 million tons and 8.48 million tons, respectively. Northern hemisphere accounts for 85% of the world ship emissions, the North Atlantic and the North Pacific region for 52% and 27% respectively of global ship emissions. (Davies, Plant, Cosslett, Harrop, &Petts, 2000) claims that on average, 57 kg of NOX is released per ton of fuel by medium-speed engines and 87 kg NO_X per ton by slow-speed engines. More recent study by (Corbett, Fischbeck, &Pandis, 1999) provides for global inventory of 3.08 tera-gram per year for nitrogen and 4.24 tera-gram per year for sulphur, respectively. More details of emissions by region are listed in the following table.

Table 2.1. Emissions by region (kt/year) (Source: Corbett et al., 1999)

	Nitrogen from ships	Sulphur from ships
Global ships emissions	3080	4240
Northern hemisphere	2630	3620
North Atlantic	1610	2220
North Pacific	820	1140
North Indian	180	250
North of Russia	10	20
Southern hemisphere	450	620
South Atlantic	130	170
South Pacific	230	320
South Indian	90	130

The total deposition of sulphur from ships by (Swindle, 1995) shows similar snapshot to the one by (Corbett et al., 1999) as presented in figure 2.1. In the graph, the majority of global sulphur and nitrogen emissions occur in northern hemisphere countries, particularly in EU. Combined with the dense population in EU, this characterization of high emissions and the population density brought about serious awareness of regulating the emissions. The enhanced awareness has led to various regulatory regimes including their regional and national legislation on environment, finally leading the initiation of adopting the ECA as the first one in the world since 2005 by IMO. Figure 2.2 shows that concentration decays exponentially away from source of pollutions. The graph indicates that most pollutants are concentrated on near shore areas such as port and coastal areas. In fact, according to the study by (Mylona, 1999), 90% of total SO2 and NOx emissions from the North Sea originated from 50 nautical miles from the coastline. Some predicted total sulphur emissions in the English Channel resulted in long-term average coastal ground level concentration of 2.5 to 3.5 µg/m3. But the same study shows that the busiest ports can be as high as 170 µg/m3. (Lowles&ApSimon, 1996). This clearly emphasizes the importance of monitoring the emissions and concentration levels in port territory for other regions.

Various studies on estimating global NG emission show greatest differences with the maximum factor of 5.6 among them. Numerous reasons can be ascribable to the differences and more common causes of the differences can be associated with different assumptions of fleet compositions, emission factors, major fuel types, engine types and methodology differences largely between top-down approach and bottom-up approach. Even the more detailed bottom-up approach can make differences depending upon what further detailed methods are used, and these are further explained in next chapter regarding the methodology. In addition, the scope of work also can be an important source of the differences, particularly as numerous studies only focused on domestic shipping whereas some few ones focused on international shipping with very few estimating both.

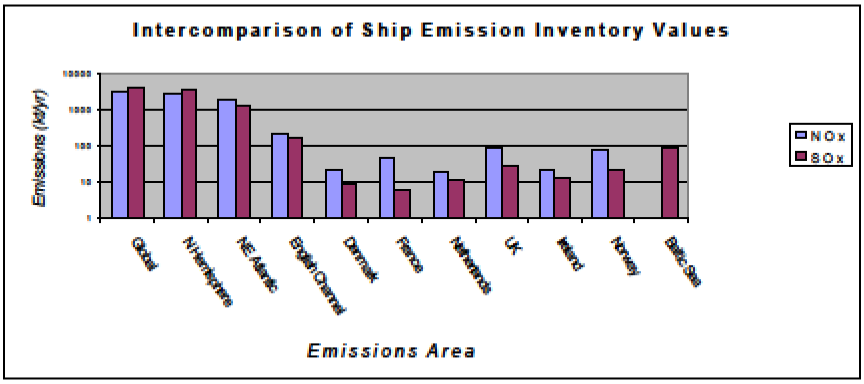

Figure 2.1. Total deposition (mg/m^2) of sulphur from ships. (Source: Swindle, 1995)

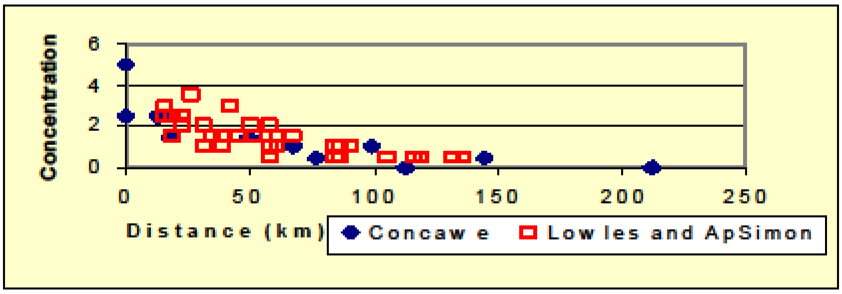

Figure 2.2. Dispersion characteristics of SO_2 from ships (μg/m^3) (Source: Concawe, 1994; Lowles&ApSimon, 1996)

As far as the NG's impact on natural environment is concerned, the concept of critical load needs to be defined. The critical load refers to the maximum amount of deposition that ecosystem can accept without becoming acidified. In other words, beyond the critical load, the nature becomes acidified. The usual serious impacts of NG on the nature are acidification and smog. The sulphur is a major source of the acidification together with nitrogen though the nitrogen also brings about fertilization or eutrofication. Acidifying gases such as SO_X and NO_X can travel considerable distances before being deposited in the environment. Therefore, high concentrations of the gases can be observed even in places where the emissions are low. This transboundary problem has been major issue of regional and international communities (BMT, 2000). To address the issue of acidifying emissions, EU has formulated various ever-stringent regulations and policies as follows (BMT, 2000):

- The EC Directive 88/609/EEC (on the limitation of emissions of certain pollutants into the air from Large Combustion Plants)
- The EC Directive 99/32/EEC (relating to the sulphur content of certain liquid fuels)
- Legislation relating to control of emissions from mobile sources: land bound mobile sources which ranged from passenger cars to light commercial vehicles ((EC Directive 70/220/EEC) as amended; heavy duty vehicles (EC Directive 88/77/EEC as amended); control of emissions from non-road mobile machinery in 1995 (COM (95) 350 final).
- The framework Directive 96/61/EC (on Integrated Pollution Prevention and Control (IPPC))
- The framework Directive on ambient air quality assessment and management (96/62/EEC)

- Appendix 2-Atmospheric Emissions and Impact A2.20 ozone.
- Strategy to Combat Acidification (COM(97)88 final)

As a result of such policies and strategies, EU emissions were reduced remarkably, 40% of SO2 between 1985 and 1994, surpassing their original target of 35% reduction (BMT, 2000). Along with this line, studies done by (Concawe, 1994; Lowles&ApSimon, 1996) show that estimated levels of deposited sulphurs from shipping in major EU port/urban areas are far below critical loads guided by WHO as presented in table 2.2. However, when focused on distinction between in-port area, within territorial waters and outside territorial waters, table 2.3 shows quite different picture as in-port area presents much higher deposition level than the WHO guidelines. Therefore, more attentions should be paid to the emission areas from ships, which are closer to port territory.

Table 2.2. Estimated deposited sulphur from shipping emissions (mg/m^2•year) (Source: Concawe, 1994; Lowles&ApSimon, 1996)

Area	Concawe (1994)	Lowles&ApSimon (1996)	Critical Load guideline (WHO, 1999)
Rotterdam/Europort	732	250	3200
Antwerp	528	200	3200
Calais/Dover	465	350	3200

Table 2.3. Deposition of sulphur due to ships in-port, within territorial waters and outside territorial waters (mg/m^2•year) (Source: Concawe, 1994; Lowles&ApSimon, 1996)

category	Concawe (1994)		Lowles&ApSimon (1996)	
	Highest deposition rate	Grid square area	Highest deposition rate	Grid square area
In-port	549	Rotterdam	7000-20,000	Rotterdam
Within territorial waters	308	Dover&Ramsgate	300	Dover
Outside territorial waters	101	Dunkirk	350	Dover Strait region

Chapter 3 Methodology and Data

3.1 Methodology

This study estimated the NG emissions by individual vessels at every stage of their movement from the moment of port entry to their departure. To capture fuel consumption and corresponding NG emissions across these stages and based on various vessel characteristics, this study first estimates how much fuel a vessel consumes during its movement. The fuel consumption of a vessel for a given navigation distance was estimated by considering the amount of fuel required for the main and auxiliary engines on a daily basis (Corbett et al., 2009).Fuel consumption by the main engine follows the cubic law of the design and operational speed. This method was used to estimate the GHG emissions in Kaohsiung harbor of Chinese Taipei (Chang and Wang, 2012). The present study adapted this approach to the availability of data from the POI. In this regard, the fuel consumption of a vessel at each stage of port movement can be expressed as follows:

$$F_{ijk} = [MF_k \bullet (\frac{s_{1k}}{s_{0k}})^3 + AF_k] \bullet \frac{d_{ij}}{24 s_{1k}} \tag{1}$$

whereF_{ijk}: amount of consumed fuel by vessel *k* moving from *i* point to *j* point

MF_k:daily fuel consumption of a vessel's main engine

AF_k: daily fuel consumption of a vessel's auxiliary engine

s_{1k}: vessel's operating speed (nm/hour)

s_{0k}: vessel's design speed (nm/hour)

d_{ij}: distance from *i* point to *j* point

Equation 1 shows the calculation method using the Tier 3 approach of (EEA, 2009)covering an individual vessel's entire trip to a port area and segmenting the trip movements into cruising, maneuvering and hotelling. Once the fuel consumption is estimated, the NG emissions can be estimated using equation 2 (EEA, 2009).

$$E_{trip,k,p,g,f} = \sum_m (F_{g,f,m} \times EF_{p,g,f,m}) \tag{2}$$

where, E_{trip}: emission over a complete trip (ton) of vessel k

$F_{g,f,m}$: amount of fuel consumed by vessel *k*

EF: emission factor

p: pollutant (NO_X, SO_2, PM)

f: fuel type (bunker fuel oil, marine diesel oil/marine gas oil, gasoline) g: engine type (slow-, medium-, and high-speed diesel, gas turbine and steam turbine)

m: different phase of the trip (cruise, hotelling, maneuvering)

Finally, as for the impact on environment and their socio-economic costs, this study adopts 'benefit-transfer' approach, which means that parameter values obtained from other studies are used in case data access, time and budget are constrained as is the case of this study. The details will be more explained in results chapter.

3.2 Data Collection

The data needed to estimate the fuel consumption based on equation 1 include the following: (1) fuel consumption by the main engine (MF_k) and auxiliary engine (AF_k) based on the type of vessel and the stage of the vessel's movement; (2) operating speed (S_{1k}) at each stage of the vessel's movement and design speed (S_{0k}) by the vessel type; and (3) navigation distance at each stage of vessel movement (d_{ij}).

This data was obtained from the Incheon Port Authority (IPA), and included 13,829 vessels processed by the POI from January to October 2012. The data set included 2 navy vessels and 43 vessels with missing data. Therefore, these vessels were excluded to give a final sample of 13,784 vessels for analysis. Each vessel has information on the time of port arrival and its docking time, undocking time, departure time, gross tonnage, nationality, vessel type, call number, assigned berth, cargo type, and cargo amount. The data contained no information on the operating speed during vessel movement after port entry. Therefore, additional data was obtained from the POI's pilot association for practical information, including the vessel's operating speed and navigation distance and the amount of time it spends during each stage of its movement. The vessels' fuel consumption was analyzed at each stage of its movement, which requires data on its engine power (kwh), fuel consumption rate (g/kwh), and engine load factor. Data on the fuel consumption rate and load factor were obtained from a previous study (Chang and Wang, 2012; Corbett et al., 2009). The engine power was estimated based on previous research (European Environment Agency, 2002; Villalba and Gemechu, 2011) and its adaption to the POI context. Table 3.1 lists the estimated engine power of main engines and auxiliary engines by vessel type.

The data on the vessel design speed by the vessel type were collected. Based on the guidance from major shipbuilding yards in Korea, and experts in shipbuilding research institutes, the data on the design speed were collected from the magazine, *Significant Ships* (Royal Institution of Naval Architects, 1997-2001). The data on the design speed were obtained for the 1996-2001 period, which was assumed to cover most vessels processed by the POI. Table 3.2 lists the results for the operating speed and design speed.

Using the similar approach used in POI, the data on PON in China were also collected for two years between 2012 and 2013. The total number of ships in 2012 and 2013 were 25,107 and 26,134, respectively. The vessels were mainly container ships, tanker and bulk carriers as well as small number of tug boats, barges and other miscellaneous ships. Ships' speed and time passage along different segments of movement between anchoring, maneuvering, docking/cargo-handling and departure were also collected.

Table 3.1. Estimated engine power

	Estimated Main Engine Power kW (total power of all engines)						Estimated Auxiliary Power kW(medium speed)						
	<500	500-999	1000-4999	5000-9999	10000-49999	>=50000	<500	500-999	1000-4999	5000-9999	10000-49999	>=50000	No. of ships
LNG	650	700	2,250	5,350	11,600	15,200	75	100	125	300	400	1,000	146
LNG	650	700	2,250	5,350	11,600	15,200	75	100	125	300	400	1,000	363
Tug	3,000	4,050	6,540	-	-	-	40	60	150	-	-	-	1,935
Passenger/RORO	600	2,000	6,500	12,300	16,650	-	100	150	350	1,000	2,500	-	1,039
Chemical Tanker	1,000	1,500	2,000	5,000	10,250	14,000	40	50	165	300	435	530	396
Tug	3,000	4,050	6,540	-	-	-	40	60	150	-	-	-	713
Chemical Tanker	1,000	1,500	2,000	5,000	10,250	14,000	40	50	165	300	435	530	22
General cargo	550	950	1,800	5,500	8,500	-	20	40	175	300	380	-	264
Refrigerated Cargo	900	900	3,100	8,850	10,000	-	40	140	180	455	580	-	30
Bulk Dry	550	750	2,700	5,000	8,800	17,000	20	40	175	300	380	500	456
Bulk Dry	550	750	2,700	5,000	8,800	17,000	20	40	175	300	380	500	479
Chemical Tanker	1,000	1,500	2,000	5,000	10,250	14,000	40	50	165	300	435	530	1,724
Container	1,000	1,750	2,950	6,000	17,200	35,000	40	60	160	500	1,400	1,400	86
Bulk Dry	550	750	2,700	5,000	8,800	17,000	20	40	175	300	380	500	226
Passenger	550	750	3,350	7,800	16,800	50,000	100	150	350	1,000	2,500	4,000	75
Other fishing	650	800	2,300	5,300	5,400	-	40	105	180	550	550	-	16
Chemical Tanker	1,000	1,500	2,000	5,000	10,250	14,000	40	50	165	300	435	530	57
General cargo	550	950	1,800	5,500	8,500	15,000	20	40	175	300	380	500	2,641
Ro-Ro	1,500	1,900	4,300	7,200	11,600	12,550	100	150	350	1,000	2,500	4,000	401
Chemical Tanker	1,000	1,500	2,000	5,000	10,250	14,000	40	50	165	300	435	530	855
Other Activities	500	900	3,300	7,650	8,500	-	40	60	150	300	500	-	206
Container	1,000	1,750	2,950	6,000	17,200	35,000	40	60	160	500	1,400	1,400	1,654

Table 3.2. Operating/design speed

Ship Type	Gross Tonnage	MCR*	Operating Speed (knot)	Design Speed (knot)
LNG Carrier	93,765	0.88	20.3	23.1
LPG Carrier	4,693	0.88	15.0	17.1
Towing Tug Vessel	4,480	0.85	16.2	19.1
International Car Ferry	21,005	0.85	18.0	21.2
Fuel Supplies Vessel	1,174	0.88	12.0	13.7
Other Tug Vessel	1,174	0.88	12.0	13.7
Other Chemical Tanker	4,693	0.88	15.0	17.1
Other Cargo Vessel	1,174	0.88	12.0	13.7
Refrigerated Cargo Vessel	3,886	0.85	19.0	22.4
Sand Carrier	1,174	0.88	12.0	13.7
Dry Bulk Carrier	28,707	0.88	14.8	16.9
Chemical Tanker	4,693	0.88	15.0	17.1
Semi-container Vessel	4,450	0.90	15.6	17.3
Cement Carrier	4,450	0.90	15.6	17.3
Passenger Ship	10,067	0.90	14.7	16.3
Deep-sea Fishing Vessel	4,480	0.85	16.2	19.1
Crude Oil Carrier	51,793	0.90	14.0	15.6
General Cargo Vessel	4,450	0.90	15.6	17.3
Car Carrier	50,938	0.85	22.0	25.9
Chemical Product Carrier	4,693	0.88	15.0	17.1
Scrap Carrier	1,898	0.88	11.0	12.5
Full-container Vessel	25,800	0.90	21.0	23.3

* Maximum continuous rating

Chapter 4 Results and Discussions

4.1 Results of NG emissions

4.1.1 The results of emissions in POI

Figure 4.1 shows average turn-around time by vessel type and also the time spent by every stage of movement among cruise, hoteling and waiting at anchorage in POI. The towing vessels spend the longest hours in the port as they have to wait usually in anchorage areas till they are called to serve the incoming and outgoing vessels. The high-end value cargo carriers such as full-container, international car ferry and car carriers spend shortest time due to their high opportunity costs of time.

To estimate the NG emissions using equation 2, data on the parameter values of the emission factor by the engine type, fuel type and movement phase were collected from (EEA, 2009). The study also shows the percentage of fuel types used by the different ship category. Using this information, it was assumed that most ships use bunker fuel oil (BFO) except for fishing vessels and tug vessels, which use mostly marine diesel oil (MDO) or marine gas oil (MGO).

Figure 4.2 shows fuel consumption by vessel type and the stage of the vessel's movement. International car ferries, full-container vessels, general cargo vessels and car carriers are major consumers of fuels in the port. General cargo vessels make the most frequent use of the POI, followed in order by tug vessels, chemical product tankers, full container vessels, and international car ferries. Their mean gross tonnages were 7,399, 171, 4,161, 11,520 and 19,119 tons, respectively. The vessels consumed a total of 22,971 tons of fuel in 2012. International car ferries made the highest total fuel consumption, followed in order by full container vessels and car carriers. Car carriers show the highest fuel consumption per vessel, followed in order by international car ferries and passenger vessels.

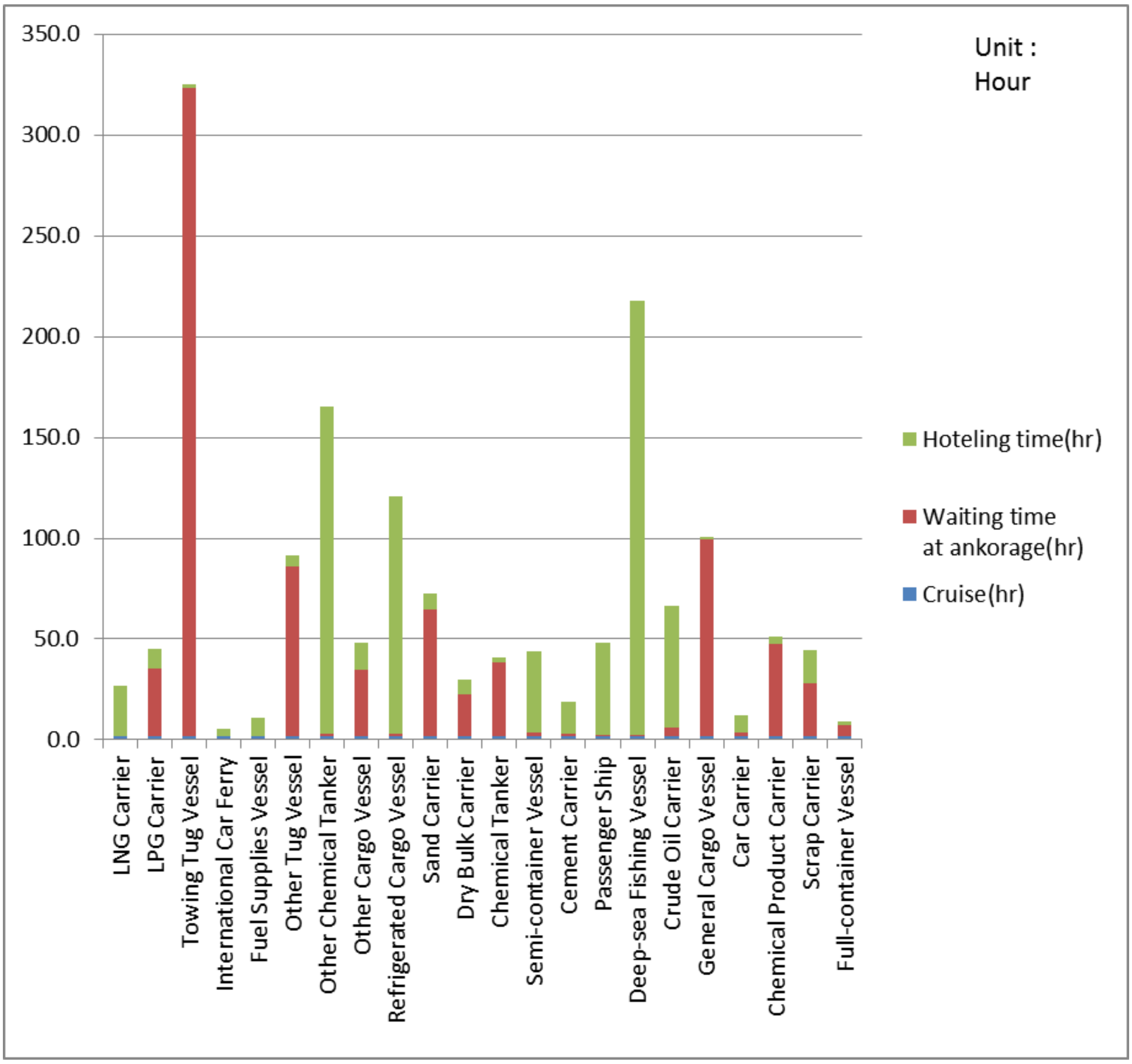

Figure 4.1. Average turn-around time by vessel type in POI

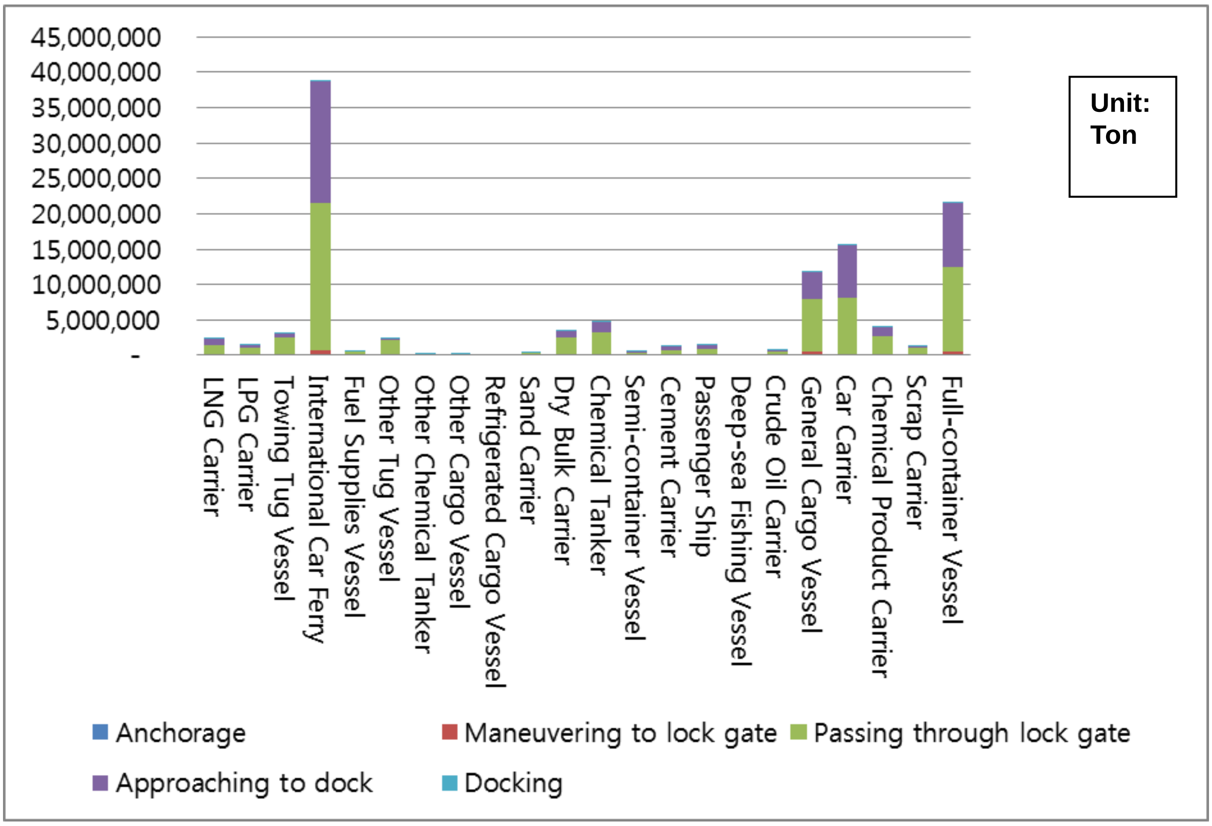

Figure 4.2. Estimation of the fuel consumption according to the ship type and movement in POI

The emissions of SO_2, NO_X and PM of the individual vessel over the segmented movements were estimated using equations 1 and 2. The SO_2 and NO_X emissions show very much same pictures to the fuel consumption as they are highly correlated with the fuel consumptions. Figures 4.3 -4.5 show the emissions of SO_2, NO_X and PM. PM emissions show only slightly different picture from the SO_2 and NO_X due to the different emission factors between them. International ferries, containers vessels and general cargo vessels are major contributors to the all three NG emissions. In addition, most of emissions occur during the cruise phase and also maneuvering. It strongly indicates that fuel consumption and their consequent NG emissions occur during the high speed period, therefore, implies that enforcing vessels to slow-steam in certain areas as is the case of the Port of LA/Long Beach will reduce considerable portions of the emissions. More details are described below.

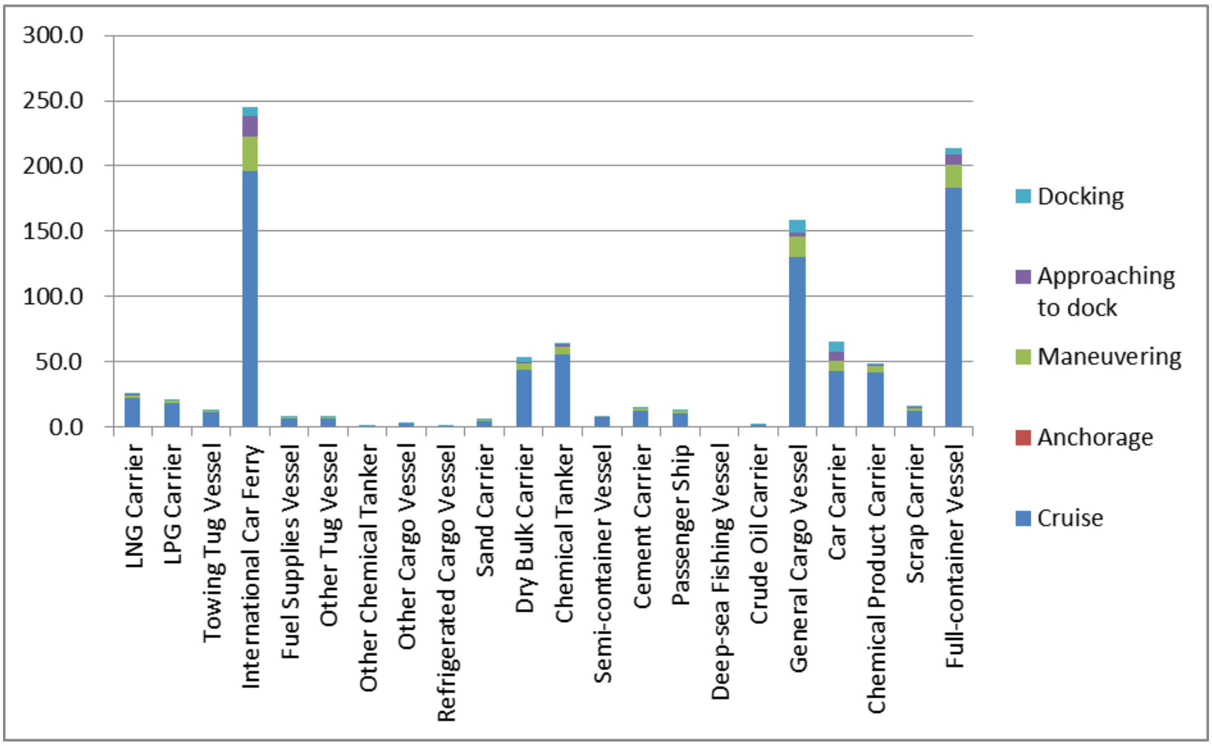

Figure 4.3. SO_2 emission by vessel type and movement in POI

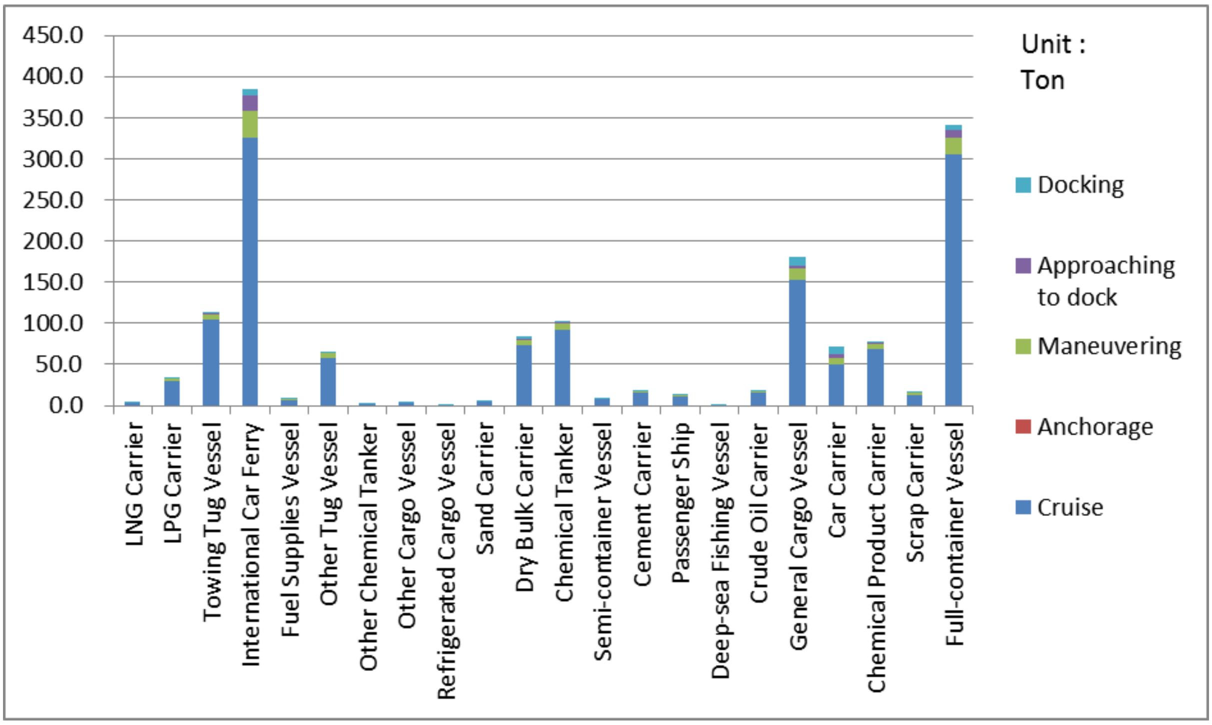

Figure 4.4. NO_X emission by vessel type and movement in POI

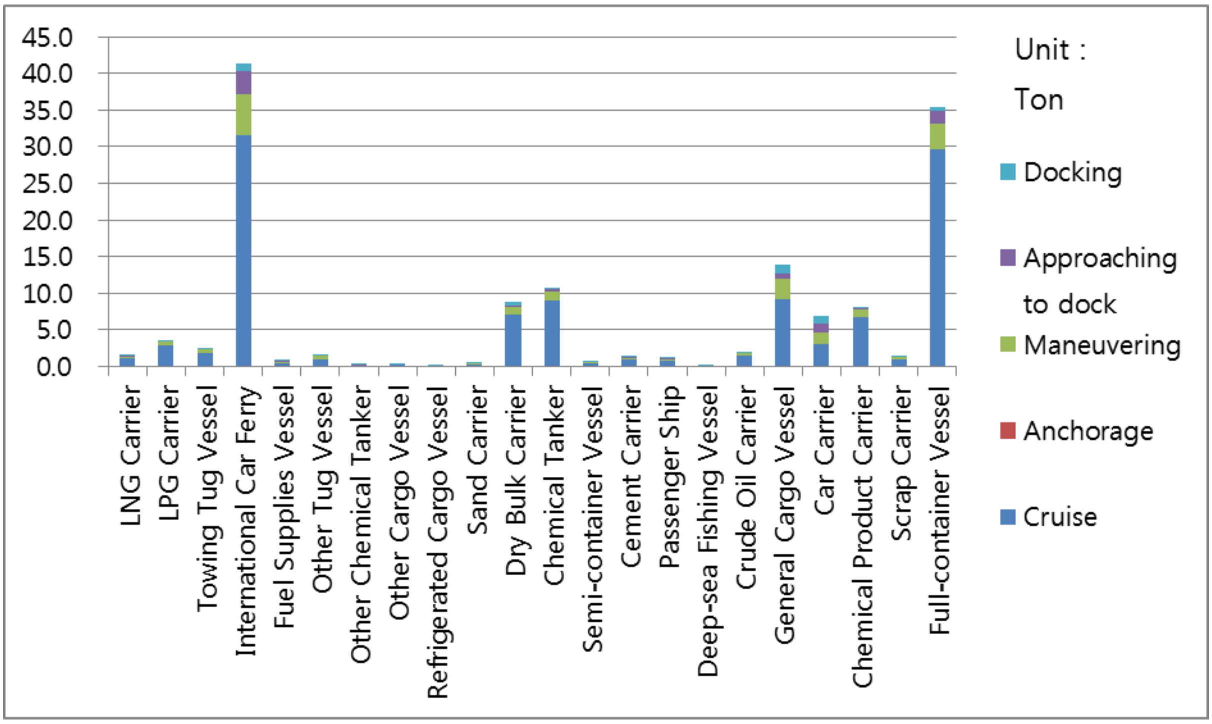

Figure 4.5. PM emission by vessel type and movement in POI

Table 4.1 lists the total amount of each pollutant over the movement. POI emitted 990 tons of SO_2, 1,551 tons of NO_X and 142 tons of PM in 2012. The amounts of sulfur emissions in this study were somewhat similar to those reported elsewhere (Wang and Corbett, 2007) in terms of the emission-to-fuel consumption rate. The per vessel emission was 72 kg of SO_2, 112kg of NO_X and 10 kg of PM. 82% of SO_2, 87% of NO_X and 76% of PM emissions occurred during the cruise phase. The emissions of SO_2, NO_X and PM were considerable during the maneuvering phase, showing 14%, 10% and 20%, respectively. A study by the EEA (EEA, 2009) revealed the same emission factor for both PM2.5 and PM10 so the same amounts are emitted. Despite the public concern regarding emissions during docking/hoteling phase, the portion of emissions for all pollutants at this phase were insignificant, comprising 4-5 % of the total emissions compared to the other movement phases. The findings in the table can be summarized as follows: SO_2 and NO_X emissions are dominated by the high speed vessel operation phase. PM is also emitted mostly in a high speed phase, but they showed considerable amounts of emissions during the low-speed maneuvering phase, being the highest during the slow-speed operation among the three pollutants.

Table 4.1. Total emissions of SO_2, NO_X and PM over the vessel movement phase in POI

(unit: ton)

	Cruise	Anchorage*	Maneuvering	Approaching to dock	Docking	Total Emission	Average per vessel
SO_2	811	0.02	99.0	40.1	39.4	989.6	0.072
%	82.0	0.0	10.0	4.0	4.0	100	-
NO_X	1,341	0.03	117.7	43.9	47.6	1,550.7	0.112
%	86.5	0.0	7.6	2.8	3.1	100	-
PM2.5/10**	109	0.00	20.5	8.1	5.2	142.4	0.010
%	76.2	0.0	14.4	5.7	3.6	100	-

* This phase refers to vessel movement of starting maneuvering from the anchorage to passing through the lock gates.

** $PM_{2.5}$ and PM_{10} have the same emission factors from the study by (EEA, 2009)

Regarding the SO_2 emissions, international car ferries are the highest polluters in both the total amount and per vessel amount as shown in table 4.2and figure 4.3. The next highest polluters in the total amount were full container vessels, general cargo vessels, car carriers and chemical tankers in that order, and the order of the per vessel amount after international car ferries was LNG carrier, passenger ship, car carriers and full container vessels. The estimation results of SO_2 according to the vessel type and movement suggested that the POI should consider introducing a speed-reduction zone in its future potential ECA to reduce the emissions during the cruise phase, which has been implemented in some countries, e.g. Ports of LA and Long Beach in the USA. The results of NO_X and PM also showed a similar pattern to that of SO_2 in terms of the major contributing vessel group to the inventory as shown in tables 4.3 -4.4 and figures 4.4-4.5. International car ferries, full container vessels and car carriers were the major polluters in both the total amount of NO_X and per vessel amount. The other notable vessel groups are general cargo vessels, tug vessels and chemical tankers in the total amount and crude oil carrier, dry bulk carriers and passenger ships in the per vessel amount. Again, international ferries, full container vessels and car carriers were the major contributors to PM in both the total amount and per vessel amount together with dry bulk carriers. General cargo vessels and chemical tankers are also major polluters in total PM emissions as are crude oil carriers and passenger ships in the per vessel PM emissions. The common phenomenon over the three pollutants is that five groups of vessels, namely international ferries, full container vessels, general cargo vessels, car carriers and chemical tankers comprise 70-76 % of their respective total emissions. This suggests that future reduction measures should be focused on these groups of vessels. In addition, all passenger vessels showed high per unit emissions for all three gases, whereas dry-bulk carriers showed high SO_2 and NO_X emissions, crude-oil carriers showed high NO_X and PM emissions, and LNG carriers showed SO_2 emissions. As the IPA plans to expand its international ferry and cruise terminal in the near future to accommodate mega size ships, this will contribute unprecedented amounts of NG to the inventory due to the high emission factor of vessels. One of the commonly adopted approaches by advanced economies to reduce the NG is to designate an Emission Control Area in the POI area.

Table 4.2. Estimation of SO_2 emissions according to the vessel type and movement phase in POI

(unit: ton)

Ship Type	Cruise	Anchorage	Maneuvering	Approaching to dock	Docking	Total emission	Average per vessel
LNG Carrier	22.4	0.0	2.0	0.9	0.9	26.2	0.179
LPG Carrier	18.0	0.0	2.1	0.4	0.5	21.0	0.058
Towing Tug Vessel	11.8	0.0	1.1	0.1	0.3	13.2	0.007
International Car Ferry	195.6	0.0	27.2	15.5	7.2	245.6	0.236
Fuel Supplies Vessel	6.6	0.0	1.1	0.1	0.2	8.0	0.020
Other Tug Vessel	6.4	0.0	1.0	0.0	0.1	7.6	0.011
Other Chemical Tanker	0.8	0.0	0.1	0.0	0.0	1.0	0.046
Other Cargo Vessel	2.6	0.0	0.4	0.0	0.2	3.3	0.012
Refrigerated Cargo Vessel	0.4	0.0	0.0	0.0	0.0	0.5	0.016
Sand Carrier	4.6	0.0	0.7	0.1	0.1	5.4	0.012
Dry Bulk Carrier	44.0	0.0	5.2	0.8	3.5	53.5	0.112
Chemical Tanker	55.4	0.0	6.5	1.2	1.8	64.9	0.038
Semi-container Vessel	6.3	0.0	0.7	0.2	0.2	7.4	0.086
Cement Carrier	12.9	0.0	1.5	0.3	0.4	15.2	0.067
Passenger Ship	10.5	0.0	1.5	0.5	0.3	12.8	0.171
Deep-sea Fishing Vessel	0.1	0.0	0.0	0.0	0.0	0.1	0.006

Crude Oil Carrier	1.7	0.0	0.2	0.0	0.0	2.0	0.035
General Cargo Vessel	130.7	0.0	14.8	3.4	9.6	158.6	0.060
Car Carrier	42.7	0.0	8.3	6.7	7.6	65.3	0.163
Chemical Product Carrier	41.7	0.0	5.1	1.1	1.0	48.9	0.057
Scrap Carrier	12.4	0.0	2.4	0.2	0.3	15.3	0.074
Full-container Vessel	183.5	0.0	17.0	8.3	5.0	213.8	0.129
Total	811.2	0.0	99.0	40.1	39.4	989.6	

Table 4.3. Estimation of NO_X emissions according to the vessel type and movement phase in POI

(unit: ton)

Ship Type	Cruise	Anchorage	Maneuvering	Approaching to dock	Docking	Total emission	Average per vessel
LNG Carrier	2.7	0.0	0.2	0.1	1.0	4.0	0.028
LPG Carrier	29.9	0.0	2.5	0.5	0.5	33.4	0.092
Towing Tug Vessel	104.3	0.0	6.9	0.6	1.8	113.7	0.059
International Car Ferry	325.0	0.0	32.8	18.7	8.4	384.8	0.370
Fuel Supplies Vessel	7.0	0.0	0.9	0.1	0.2	8.2	0.021
Other Tug Vessel	57.1	0.0	6.6	0.2	0.8	64.7	0.091
Other Chemical Tanker	1.4	0.0	0.1	0.0	0.0	1.6	0.073
Other Cargo Vessel	2.8	0.0	0.3	0.0	0.2	3.4	0.013
Refrigerated Cargo Vessel	0.4	0.0	0.0	0.0	0.0	0.5	0.017
Sand Carrier	4.9	0.0	0.6	0.1	0.1	5.6	0.012
Dry Bulk Carrier	73.1	0.0	6.2	1.0	4.0	84.3	0.176
Chemical Tanker	92.0	0.0	7.8	1.5	2.1	103.4	0.060
Semi-container Vessel	7.4	0.0	0.6	0.1	0.3	8.4	0.097
Cement Carrier	15.2	0.0	1.3	0.3	0.5	17.3	0.076
Passenger Ship	11.3	0.0	1.2	0.4	0.2	13.1	0.174
Deep-sea Fishing Vessel	0.3	0.0	0.0	0.0	0.0	0.4	0.023
Crude Oil Carrier	15.6	0.0	1.4	0.1	0.2	17.4	0.305
General Cargo Vessel	153.5	0.0	12.7	2.9	11.1	180.2	0.068
Car Carrier	50.1	0.0	7.1	5.8	8.8	71.8	0.179
Chemical Product Carrier	69.2	0.0	6.1	1.4	1.2	77.9	0.091
Scrap Carrier	13.3	0.0	1.9	0.2	0.3	15.6	0.075
Full-container Vessel	304.9	0.0	20.5	10.0	5.7	341.1	0.206
Total	1,341.4	0.0	117.7	43.9	47.6	1,550.7	

Table 4.4. Estimation of PM emissions according to the vessel type and movement phase in POI

(unit: ton)

Ship Type	Cruise	Anchorage	Maneuvering	Approaching to dock	Docking	Total emission	Average per vessel
LNG Carrier	1.1	0.0	0.3	0.1	0.1	1.6	0.011
LPG Carrier	2.9	0.0	0.4	0.1	0.1	3.5	0.010
Towing Tug Vessel	1.9	0.0	0.5	0.0	0.1	2.5	0.001
International Car Ferry	31.5	0.0	5.6	3.2	0.9	41.3	0.040
Fuel Supplies Vessel	0.5	0.0	0.2	0.0	0.0	0.7	0.002
Other Tug Vessel	1.0	0.0	0.5	0.0	0.0	1.5	0.002
Other Chemical Tanker	0.1	0.0	0.0	0.0	0.0	0.2	0.008
Other Cargo Vessel	0.2	0.0	0.1	0.0	0.0	0.3	0.001
Refrigerated Cargo Vessel	0.0	0.0	0.0	0.0	0.0	0.0	0.001
Sand Carrier	0.3	0.0	0.1	0.0	0.0	0.5	0.001
Dry Bulk Carrier	7.1	0.0	1.1	0.2	0.5	8.8	0.018
Chemical Tanker	8.9	0.0	1.3	0.3	0.2	10.8	0.006
Semi-container Vessel	0.4	0.0	0.1	0.0	0.0	0.6	0.007
Cement Carrier	0.9	0.0	0.3	0.1	0.1	1.3	0.006
Passenger Ship	0.7	0.0	0.3	0.1	0.0	1.2	0.015
Deep-sea Fishing Vessel	0.0	0.0	0.0	0.0	0.0	0.0	0.002
Crude Oil Carrier	1.5	0.0	0.2	0.0	0.0	1.8	0.032
General Cargo Vessel	9.2	0.0	2.8	0.7	1.2	13.9	0.005
Car Carrier	3.0	0.0	1.6	1.3	1.0	6.9	0.017
Chemical Product Carrier	6.7	0.0	1.1	0.2	0.1	8.1	0.010
Scrap Carrier	0.9	0.0	0.5	0.0	0.0	1.4	0.007
Full-container Vessel	29.6	0.0	3.5	1.7	0.6	35.5	0.021
Total	108.5	0.0	20.5	8.1	5.2	142.4	

Next, this study examined how much the emissions can be reduced in a future ECA of the POI if a speed reduction is implemented with a 12 mile speed limit within the 25 mile zone similar to the LA and Long Beach case. In addition, the effect of reducing the sulfur contents with two options of 1% and 0.1 % similar to the standard of Europe and North America's ECAs was tested. The 1% sulfur limit in marine fuel is the current rule in the ECAs but the 0.1% rule will be imposed from 2015. Table4.5 lists the results. The speed reduction zone can reduce the NG emission by one third. More reductions can be realized in NO_X. When the sulfur content limit is enforced in the ECA, the 1% current rule is expected to reduce the emissions by approximately 70% and 0.1% rule is expected to reduce the emissions remarkably by 93%. This study could not estimate the results of NO_X and PM reduction using lower sulfur fuel because this approach was based on the Tier 3 approach of the EEA (EEA, 2009), which does not provide estimates of NO_X and PM when using lower sulfur fuels in the Tier 3 approach. The scenarios of these three measures were applied to current vessels using the POI. The POI plans to open its expanded mega-carrier ferry and cruise terminal with the first phase operation in 2014. Moreover, it also plans to open the New Incheon Port, beginning with 6 berths at the end of 2013 and eventually accommodating 25 container vessels and 4 general cargo vessels simultaneously by 2020 to become a global hub port. With this expansion plan in place, the amount of NG will increase sharply due mainly to increasing cargo volumes and more importantly to top-ranking NG emitting cargo vessels, such as international car ferries, passenger vessels, and full-container vessels. Therefore, designating the POI area as an ECA in Korea would result in an enormous reduction of NG emissions in the future. This study has some limitations. First, this study was unable to estimate the NO_X and PM when using lower sulfur fuels in ECA due to the Tier 3 approach of the EEA (EEA, 2009), even though the approach is the most detailed and accurate method for estimating the NG emissions. Second, the scope of the work was confined to the emissions of NG, not covering its impact on the natural environment and impact on human health. Third, the emissions focused on recent vessels that used the POI not covering the future demands at the POI. All these remain an avenue of future research.

Table 4.5. Reduction of NG emissions in a future ECA with various measures in POI

(unit: ton)

	Current	RSZ(12knots)*	RSZ(12knots)**	ECA (1.0%)+	ECA (1.0%)	ECA (0.1%)+	ECA (0.1%)
SO_2	990	668	32.47%	404	59.18%	68	93.16 %
NO_X	1,551	1,021	34.14%	-	-	-	-
PM	142	97	31.67%	-	-	-	-

* Reduced Speed Zone (RSZ) with 12 knots speed limit is enforced within 25 nautical mile zone.

** reduction percentage with RSZ system

+ 1% or 0.1% sulfur content regulation is enforced in an ECA.

4.1.2 The results of emissions in PON

Using the similar approach used in POI, the data on PON in China were analyzed for two years between 2012 and 2013. Out of the respective 25,107 and 26,134 vessels in 2012 and 2013, major vessels were container ships, tanker and bulk carriers as well as small number of tug boats, barges and other miscellaneous ships. Using the data on ships' speed and time passage along different segments of movement between anchoring, maneuvering, docking/cargo-handling and departure, the NG emissions were estimated following the Tier 3 approach as applied to POI. The estimation results are listed in table 4.6. PON emitted 6 thousand NO_X, 2 thousand SO_X and five hundred PM in 2012 and similar amounts in 2013 as well. The dominant contributing ships to the emissions were container ships followed by bulk carriers and tankers in the order. Figures 4.6-8 show the emissions again by ship type and movement. The figures show more vivid dominance of emissions by container ships. In addition, Departure from the dock and cargo handling phases incur major contributions of the emissions. Moreover, anchoring and maneuvering also show significant emissions. This is somewhat different from the results of POI. The difference between POI and PON seems to arise from different fleet composition, vessel sizes and waiting times. By analyzing the vessel sizes and fleet composition, it turns out that vessels using PON have substantial number of mega carriers such as thousands of over 100,000 DWT ships. This size of vessel emits more than ten times of NG gasses than smaller sized vessels. The difference in vessel size distribution between the two ports can be seen in figures 4.9-10.

Table 4.6. Ship emissions by activity and type of ships in PON

(unit: ton)

year	2012			2013		
Movements	NO_X	SO_X	PM	NO_X	SO_X	PM
Anchoring	1520.67	486.19	85.67	1614.44	516.17	90.95
Maneuvering	1096.75	354.13	129.94	1181.67	380.50	140.48
Handling	1624.48	519.38	91.52	1756.81	561.68	98.98
Departure	1575.30	502.98	220.17	1669.58	532.17	232.99
Total emissions	5817.20	1862.67	527.30	6222.50	1990.52	563.40
Type of ships						
Container ship	3884.86	1234.19	319.05	4095.70	1301.03	338.00
Tanker	641.49	204.87	77.37	626.77	200.15	75.24
Bulk	1220.39	400.88	126.45	1425.33	465.30	145.35
LNG	1.70	0.55	0.12	11.93	3.83	0.83
LPG	0.14	0.05	0.01	3.86	1.25	0.37
RoRo	39.53	12.64	2.27	39.53	12.64	2.27
Tug	1.99	0.72	0.28	1.17	0.42	0.17
Barge	27.10	8.77	1.75	18.22	5.90	1.18
Total emissions	5817.20	1862.67	527.30	6222.50	1990.52	563.40

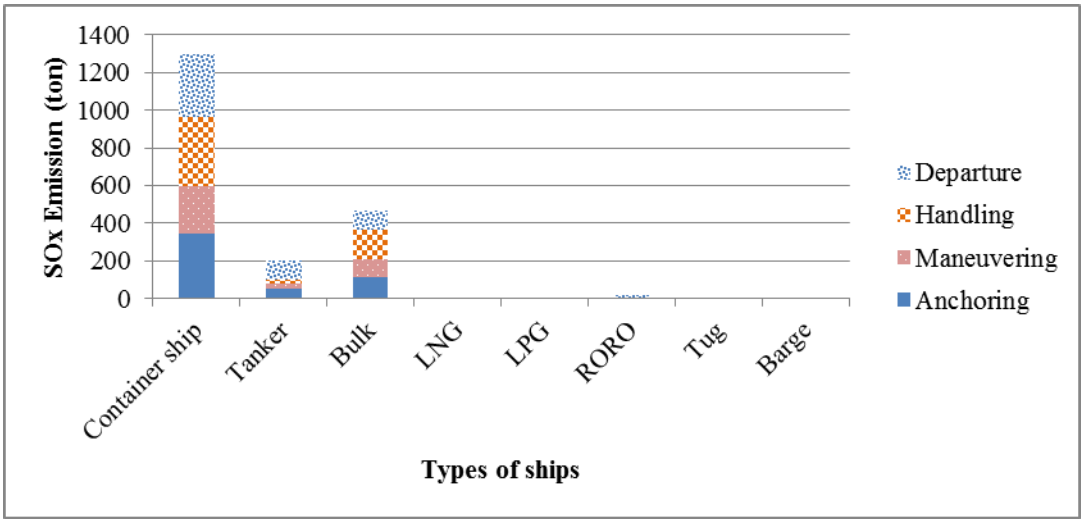

Figure 4.6. SO_X emission by vessel type and movement in 2013 in PON

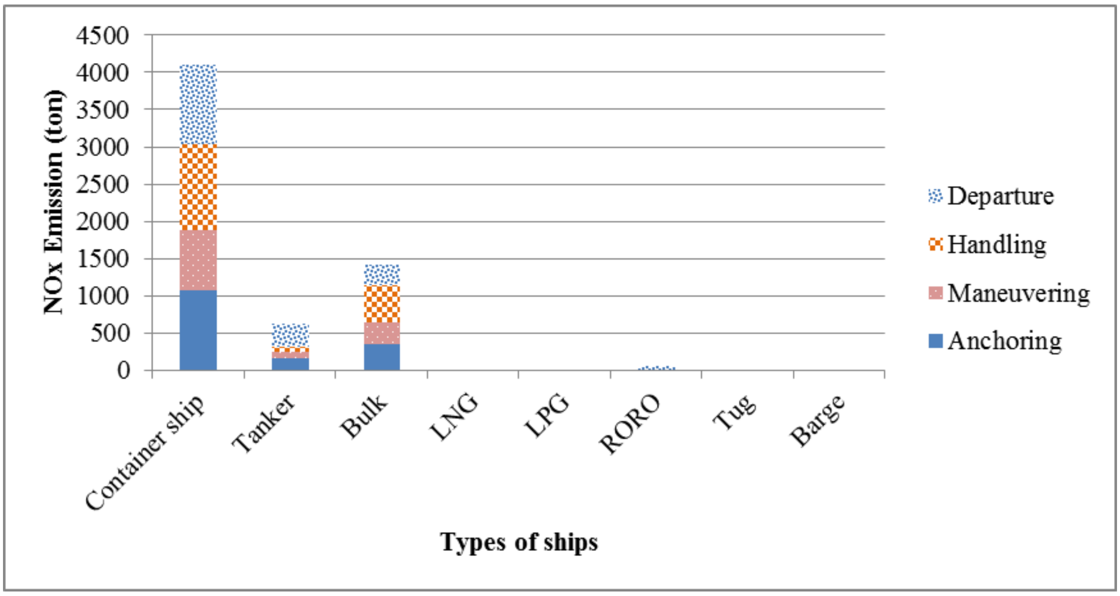

Figure 4.7. NO_X emission by vessel type and movement in 2013 in PON

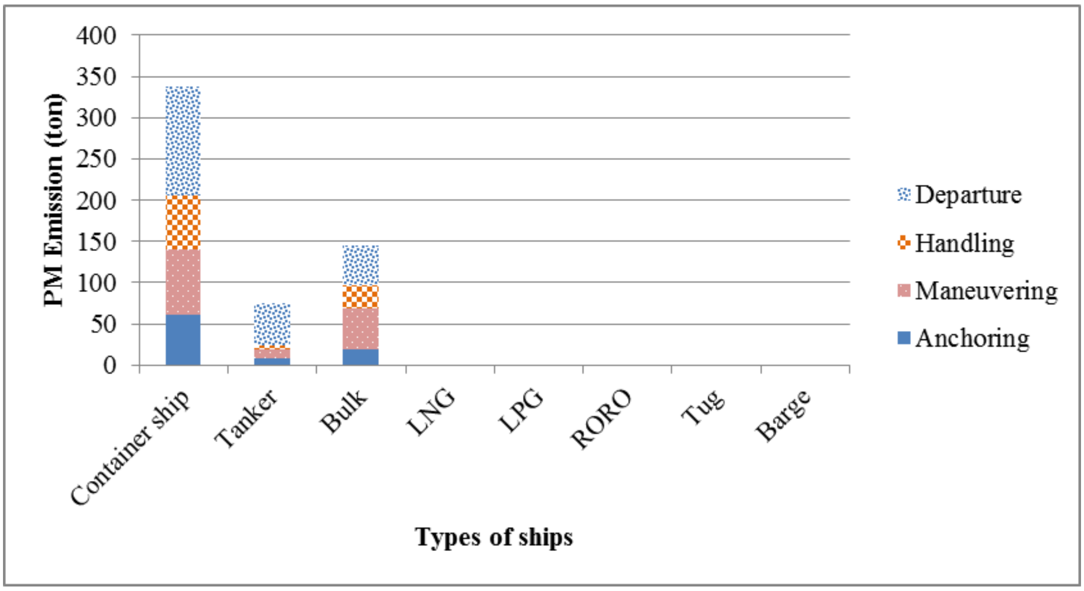

Figure 4.8. PM emission by vessel type and movement in 2013 in PON

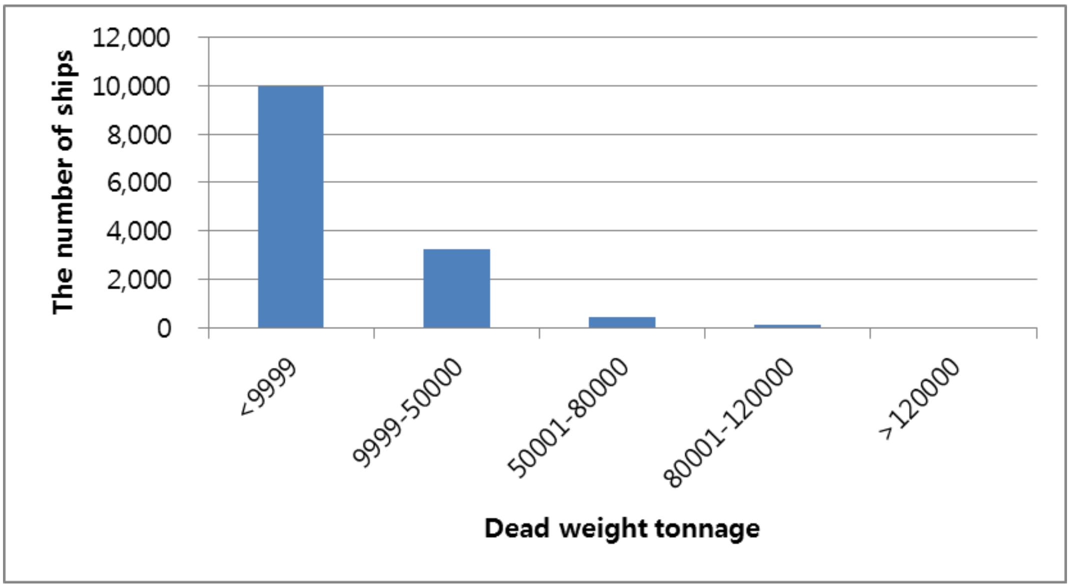

Figure 4.9. Distribution of ship size in POI

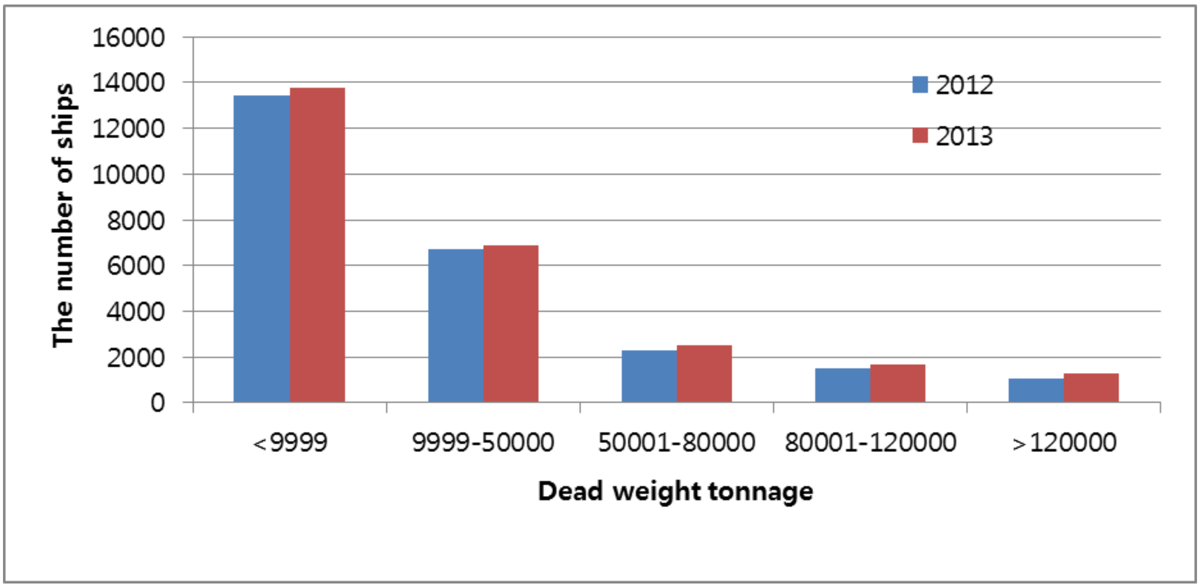

Figure 4.10. Distribution of ship size in PON

4.2 Results of environmental and socio-economic impacts by NG emissions

4.2.1 The results of environmental and socio-economic impacts in POI

The environmental impacts of the NG were estimated using the concept of external cost. The external costs are the economic opportunity cost of the side effects arising from using market goods and services such as the transportation services. Typical good examples of the external costs are congestion, air pollution, noise, accidents and infrastructure damages. These side-effects are not traded usually in market system; therefore, their prices are not determined in market trading mechanism. Instead, they should be estimated using a different method, often dominated by two representing methods: stated preferences and revealed preferences. The former approach is to draw the intension of stakeholders explicitly as for how much the afflicted people by the side effects are willing to either pay (willingness-to-pay: WTP method) for or accept (willingness-to-accept: WTA method) the damages and sufferings, respectively. On the other hand, the latter approach is to estimate the price of the side effects statistically, which are inherently revealed in market priced system for instance, the noise and view affect the housing price in the market. This study used also the willing-to-pay method to estimate the external costs of NG emissions. Though the external costs can vary depending upon geo-economic characteristics due to different effects of dispersions, concentrations and impacts of the NG on human population, furthermore, income structure of the human population, building all the integrating models from NG emissions to the impact requires a grand scale of research, which is certainly beyond the scope of this work. Therefore, to estimate the external costs of NG, most relevant parameter values for the external costs by NG emission are referenced from the work by (Lee, Kai-Chieh Hu, & Chen, 2010). They estimated the external costs of various air pollutants from short sea shipping as well as other transportation modes in Chinese Taipei. As the shipping in POI is similar to the short sea shipping and the economic development status between Chinese Taipei and Korea can be assumed to be as same as the purpose of this study is concerned, the same parameter values are used for this study. The results are listed in table 4.7.The total external costs of NG from ships in POI are approximately over 75 million dollars. Of these, PM cost comprises 71 %, followed by 18% for SO_2 and 10 % for NO_X. The external cost per vessel is over five thousand dollars. The results indicate that policies should be formulated to reduce PM more importantly then SO_2. Table 4.8 presents the annual socio-economic benefits by designating the ECA in POI using the same external cost per ton of NG. The speed control option to 12 knots can provide for over 24 million dollars. Current ECA system of controlling the sulphur content to 1% and 0.1% rule scheduled to be implemented on January 1st, 2014 can provide 8 million and 13 million dollars, respectively excluding other benefits from NO_X and PM.

Table 4.7. External costs of total emissions of SO_2, NO_X and PM from ships in POI

(unit: US$)

Pollutant	External cost/ton*	Total external cost	%	External cost per vessel
SO_2	13,960	13,814,940	18.4	1,002
NO_X	4,992	7,740,878	10.3	562
PM	375,880	53,512,186	71.3	3,882
total		75,067,984	100	5,446

* Source: (Lee et al., 2010)

Table 4.8. Annual socioeconomic benefits of designating ECA in POI

(unit: US$)

Pollutant	RSZ (12knots)	ECA (1%)	ECA (0.1%)
SO_2	4,486,021	8,176,308	12,869,384
NO_X	2,642,854	-	-
PM	16,948,140	-	-
total	24,077,015	-	-

4.2.2 The results of environmental and socio-economic impacts in PON

Using the same parameter values for unit external cost of NG, the external costs in PON were also estimated. The results are listed in table 4.9. The table shows similar pattern of external cost distribution among the three gases to the one in POI. But the magnitude of the external cost in PON is noteworthy due to several times more serious impact compared with POI. The total external cost in PON was estimated to be over 700 million dollars in 2012 and 760 million dollars in 2013. This is almost ten times higher impact than in POI. This must arise from much larger sizes of ships' entering PON and also dominance of container ships, which are most serious contributors to the emissions as can be seen in POI as well. Therefore, together with larger size and dominant high polluting ships in PON, the population in the vicinity must have suffered enormous environmental and health impacts arising from the vessels using the PON. This is particularly true with the high proportion of PM (84%), which is the most noxious gas among others emitted by ships, causing severe cardiovascular and pulmonary sickness. Therefore, future policies in PON should be formulated into measures to reduce emission of PM and impact by high proportional container ships.

Table 4.9. External costs of total emissions of SO_2, NO_X and PM from ships in PON

(unit: US$)

Pollutant	External cost/ton*	Total external cost (2012)	%	Total external cost (2013)	%
SO_2	13,960	52,502,237	8.4	56,323,812	8.4
NO_X	4,992	59,544,415	7.4	63,921,808	7.4
PM	375,880	595,190,736	84.2	639,266,354	84.2
total		707,237,388	100	759,511,974	100

This project attempts to develop a robust methodology in assessing the emissions of NG in the most detailed micro-level known as Tier 3 bottom-up approach. The developed methodology was applied to two case study ports: one in Korea and the other in China. Vessels data that used the Port of Incheon (POI) in Korea in 2012and the Port of Ningbo (PON) in China for two years in 2012-2013 were collected. Moreover, this study measured the emissions of SO_2, NO_X and PM from vessel operations in a potential Emission Control Area in Korea to examine the reduction effect of gases by ECA designation.

The results show that the POI emitted 990 tons of SO_2, 1,551tons of NO_X and 142 tons of PM in 2012. Most of the NG emissions occurred during the cruise phase. Five groups of vessels, namely international ferries, full container vessels, general cargo vessels, car carriers and chemical tankers comprised 70-76 % of the respective total emissions of NG. Assuming a future Emission Control Area in the POI, speed reduction measures and the effects of reducing sulfur contents with two options (1% and 0.1 %) were tested. The speed reduction zone can reduce the NG emissions by a third. Moreover, the 1% current rule can reduce the emissions by almost 70%, whereas the 0.1% rule can reduce the emissions remarkably by 93%.

PON emitted 6 thousand NO_X, 2 thousand SO_X and five hundred PM in 2012 and similar amounts in 2013 as well. The dominant contributing ships to the emissions were container ships followed by bulk carriers and tankers in the order. Departure from the dock and cargo handling phases incur major contributions of the emissions. Moreover, anchoring and maneuvering also show significant emissions. This is somewhat different from the results of POI. The difference between POI and PON seems to arise from different fleet composition, vessel sizes and waiting times. By analyzing the vessel sizes and fleet composition, it turns out that vessels using PON have substantial number of mega carriers such as thousands of over 100,000 DWT ships. This size of vessel emits more than ten times of NG gasses than smaller sized vessels.

When the emissions were converted to socioeconomic costs, the NG emissions in POI incurred over 75 million dollars annually. Moreover, designating speed reduction zone to 12 knots can provide the benefit of 24 million dollars per annum. Only adopting current ECA rule of 1% sulphur fuel and next year's 0.1% fuel rule are likely to provide socioeconomic benefits of 8 and 13 million dollars, respectively solely from reduction of SO_2. It is noteworthy that almost three quarters of the external costs arise from the emissions of PM due to its critical impact on human health.

The total external cost in PON was estimated to be over 700 million dollars in 2012 and 760 million dollars in 2013. This is almost ten times higher impact than in POI. This must arise from much larger sizes of ships' entering PON and also dominance of container ships, which are most serious contributors to the emissions as can be seen in POI as well. Therefore, together with larger size and dominant high polluting ships in PON, the population in the vicinity must have suffered enormous environmental and health impacts arising from the vessels using the PON. This is particularly true with the high proportion of PM (84%), which is the most noxious gas among others emitted by ships, causing severe cardiovascular and pulmonary sickness.

In conclusion, both ports show similar patterns of external costs among the three gases though the magnitude of the cost is almost one to ten between the two ports. The most serious problem inflicting the population in nearby residential areas must be much high proportion of PM in both ports. Therefore, future policies in the two ports should be formulated into measures to reduce emission of PM and impact by high proportional container ships.

Chapter 5 IMO Regulatory Measures

Over the last decades, the international community has been putting increasing attention to the air pollution and environmental impact from ships. As a specialized agency of the United Nation, the International Maritime Organization (IMO) serves as a global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented. (IMO, 2014)

Environmental issues are top on the IMO agenda, its Marine Environmental Protection Committee (MEPC) is the appropriate body dealing with matters relating to various forms of pollutions from ships, and has developed a set of international instruments to regulate and reduce marine and air pollutions from ships.

5.1 Overview of the IMO Regulatory Framework on Prevention of Air Pollution from Ships

The MARPOL 73/78 Convention of IMO is the most important regulatory convention in the field of prevention and reduction of ship-source marine pollutions. Operational pollution from ships is regulated exclusively under this instrument. The substantive regulatory provisions are contained in six Annexes to the Convention, each addressing a different kind of pollutant.

Annex VI contained in the Protocol adopted in 1997 to MARPOL is captioned “Regulations for the Prevention of Air Pollution from Ships”. Annex VI entered into force in May 2005. It is the cornerstone of the work of IMO to tackle with transboundary environmental harm form international shipping. In 2008, Annex VI has undergone a comprehensive revision by MEPC to impose progressive reduction standards for SO_X and NO_X emissions from ships at a global scale.

The revised Annex VI contains provisions regulating SO_X and NO_X emissions from ships as well as volatile organic compounds (VOC) from tankers and certain ozone-depleting substances. (IMO, 2014) There are 18 regulations in the revised Annex VI which are grouped respectively under three Chapters. It should also be noted that, in order to improve the energy efficiency of international shipping and control GHG emissions from ships, a new Chapter 4 was adopted by MEPC in July 2011 for inclusion of regulations on energy efficiency for ships. As GHG emissions do not fall into the scope of discussions for this study, examination in this Part will only focus on the three Chapters dealing with SO_X, NO_X as well as other harmful emissions from ships.

Chapter 1 entitled “General” contains regulations 1 to 4. Chapter 2 is “Survey, certification and means of control” which contains regulations 5 to 11. Chapter 3 is “Requirements for control of emissions from ships” where regulations 12 to 18 are provided there. These regulations are followed by Appendices I to VI covering the form of International Air Pollution Prevention Certificate; Criteria and procedures for designation of emission control areas; Type approval and operating limits for shipboard incinerators; Fuel verification procedure etc.

Similar to other MARPOL Annexes, Annex VI consists of provisions addressing topics as Definitions (regulation 2), Exceptions and exemptions (regulation 3), Equivalents (regulation 4), Surveys and Certification (regulations 5 to 9) and Port State Control (regulations 10 and 11). Under regulation 12 deliberate emissions of ozone-depleting substances are prohibited with some exceptions. Regulation 13 addresses control of NO_X emissions and regulation 14 with control of SO_X and PM emissions including requirements applicable within emission control areas (ECA). Regulation 15 deals with volatile organic compounds from tankers. Regulation 16 addresses shipboard incineration. Regulation 17 requires facilities to be provided for the reception of ozone depleting substances including exhaust gas cleaning residues, the discharge of which is prohibited. Regulation 18 provides for fuel oil availability and quality.

As mentioned earlier, regulation 13 deals with the control of NO_X emissions under which the NO_X Technical Code is developed and made mandatory requirements. The purpose of this Code is to provide procedures for the testing, survey and certification of marine diesel engines. These procedures will enable Administrations, ship owners and engine manufacturers to ensure that all applicable marine diesel engines comply with the relevant NO_X limiting emission values as specified within regulation 13 of Annex VI. The NO_X Technical Code has also been revised in 2008.

5.2 SO_X Emission Regulations

Ships' SO_X and PM emissions are mainly dealt with by regulation 14 of Annex VI. These regulations are applicable to all fuel oil, combustion equipment and devices used and installed on board ships, therefore both main and auxiliary engines together with boilers and gas generators are included.

The control of SO_X and PM emissions in these regulations are primarily achieved by limiting the maximum sulphur content of the fuel oils loaded on board ships, and different limit standards are provided inside ECAs and outside such areas. Time schedules are also specified for ships to comply with steadily stricter limits over the years. The table 5.1 shows the fuel oil sulfur limits.

Table 5.1. Annex VI Reg.14-fuel oil sulfur limits

Date	Sulfur Limit (% m/m)	Date	Sulfur Limit (% m/m)
	Global		SO_X ECAs
prior to Jan. 2012	4.5%	prior to Jul. 2010	1.5%
Jan. 2012-Jan.2020	3.5%	Jul.2010-Jan. 2015	1.0%
after Jan. 2020*	0.5%	after Jan. 2015	0.1%

* an alternative date is Jan. 2025 subject to a review by 2018.

The existing ECAs established in accordance with the criteria and procedures set forth in Appendix III to Annex VI are shown in table 5.2.

Table 5.2. Existing emission control areas

Areas	Controlled Emissions	Effective Date
Baltic Sea	SO_X	May 2006
North Sea	SO_X	Nov. 2007
North American (including most of US and Canadian coast)	SO_X, NO_X and PM	Aug. 2012
United States Caribbean Sea	SO_X, NO_X and PM	Jan. 2014

In order to comply with respective limits inside and outside of ECAs, ships should operate on different fuel oils. The changeover of ECA compliant fuel oil is required for ships prior to entry into such areas, and details of each changeover are required to be documented. In this circumstance, the control of the actual sulphur content of the fuel oil as bunkered is very important. This value is to be provided on the bunker delivery note by the fuel oil supplier. Regulation 18 of Annex VI requires that ships' crew ensure the quality of fuel oil to be compliant with applicable standards as specified in regulation 14.

Though regulation 14 provides both the emission limits and means for ships to comply, alternative means are also permitted as long as equivalent levels of SO_X and PM both inside and outside of ECAs could be met. Regulation 4 of Annex VI provides flexibility to Administrations to allow the use of alternative fuel oils or compliance methods (mainly exhaust gas scrubbing technology) under the condition that they are at least effective as those required under Annex VI in terms of emissions control and reductions.

5.3 NO_X Emission Regulations

With respect to the control of NO_X emissions, regulation 13 of Annex VI provides emission limits for diesel engines depending on the engine maximum operating speed. This is to be achieved through the survey and certification requirements to demonstrate that ships are in compliance with the requirements specified in this regulation and those in the NO_X Technical Code.

These regulations are applicable to marine diesel engine of over 130 kW output power installed on board ships irrespective of the ships' tonnage. Three Tiers of emission limits are provided based on the ship construction dates, and the actual limit value is determined according to the engines' rated speed. The table 5.3 shows the NO_X emission limits.

Table 5.3. Annex VI Reg.13-NO_X emission limits (*IMO, 2014*)

Tier	Ship Construction Date on or after	Total weighted cycle emission limit (g/kWh) n=engine's rated speed (rpm)		
		n < 130	n = 130-1999	n >= 2000
I	Jan. 2000	17	$45.n^{-0.2}$ e.g., 720 rpm-12.1	9.8
II	Jan. 2011	14.4	$44.n^{-0.23}$ e.g., 720 rpm-9.7	7.7
III	Jan. 2016*	3.4	$9.n^{-0.2}$ e.g., 720 rpm-2.4	2.0

* the date may be postponed subject to a technical review by MEPC by 2013.

Only specified ships when operating inside ECAs are subject to application of Tier III standards; while outside of ECAs, Tier II standards are applicable. Existing NO_X ECAs established under Annex VI are North American area and United States Caribbean Sea area as shown in the previous table.

NO_X Technical Code provides requirements to determine the emission value a diesel engine in terms of Tier II and III limits. The certified engine will be issued an Engine International Air Pollution Prevention (EIAPP) Certificate, which should be a part of the approved Technical File as required to be carried on board ships.

5.4 Regulations on other Air Pollutants by Ships

The emissions of ozone-depleting substances are regulated by regulation 12 of Annex VI where any deliberate emissions of such substances are prohibited. Regulation 12 also provides respective time schedules for emissions prohibition for installations on board ships containing hydro-chlorofluorocarbons (HCFCs) and other ozone-depleting substances. In addition, it is also required under this regulation that ships with installations containing ozone-depleting substances maintain a record book for relevant supply, recharging, repair, discharge or disposal operations of such substances.

Regulation 15 of Annex VI provides requirements on VOC emissions which are only applicable to tankers. VOC emissions are controlled from two aspects under this regulation. In the first, VOC emissions from a tanker in certain ports or terminals are controlled by a requirement to utilize a vapor emission control system. State Parties could select ports and terminals operating under their jurisdictions to apply such controls and only to certain sizes of tankers or cargo types. IMO also adopted Standards for such systems for this purpose. In the second aspect, tankers carrying crude oil are required to carry on board an approved and effectively implemented VOC Management Plan. Such plan should be ship specific and provide necessary information on minimizing VOC emissions.

Regulation 16 of Annex VI regulates shipboard incinerators. Shipboard incineration of substances such as cargo residues regulated under MARPOL Annex I, II and III; PCBs; garbage under Annex V; halogen compounds; PVCs and exhaust gas cleaning system residues are prohibited under this regulation.

5.5 Associated Technical Guidelines

In order to provide further guidance for the implementation of the mandatory regulations, a bunch of technical guidelines have also been developed or updated by MEPC in association with the Annex VI regulations of reducing SO_X and NO_X emissions from ships.

For the reduction of SO_X emissions, relevant technical guidelines include 2009 Guidelines for the sampling of fuel oil for determination of compliance with the revised MARPOL Annex VI; 2009 Guidelines for exhaust gas cleaning systems; 2009 Guidelines for port State control under the revised MARPOL Annex VI; and 2010 Guidelines for monitoring the worldwide average sulphur content of fuel oils supplied for use on board ships.

For the reduction of NO_X and other emissions, relevant technical guidelines include 2009 Guidelines for the development of a VOC management plan; 2011 Guidelines addressing additional aspects to the NO_X Technical Code 2008 with regard to particular requirements related to marine diesel engines fitted with selective catalytic reduction systems; 2013 Guidelines as required by Regulation 13.2.2 of MARPOL Annex VI in respect of non-identical replacement engines not required to meet the Tier III limit; and Guidelines on the provision of reception facilities.

5.6 Latest Developments at IMO

The initiatives undertaken by IMO to develop MARPOL Annex VI and regulate SO_X, NO_X and PM emissions from international shipping have yielded significant outcomes. While technical deliberations on these topics are ongoing at MEPC, more focuses are being given to the issue of punctual implementation of SO_X and NO_X limits (post-2015) as a result of the fuel oil availability review under regulation 18 and the Tier III technology review under regulation 13 respectively.

As far as the SO_X emission is concerned, the compliance with Annex VI requirements are mostly dependent on the availability and sufficient supply of compliant fuel oils. As discussed in previous paragraphs, the sulphur content of fuel oil is required to fall down to 0.5% m/m on and after 1 January 2020, subject to the outcome of a review by 2018. If the review turns out that the compliant fuel oil is not available, the implementation date could be deferred to 1 January 2025.

MEPC 64 held in October 2012 discussed this issue. The shipping industry voiced serious concern on the availability of fuel oil for ships to meet with 2020 limits, and therefore called for an earlier review (2018 is required by Annex VI) by means of conducting a preliminary study on the availability of compliant fuel using the 0.1% m/m limit in ECAs in 2015 as a test case. However, as the result of the annual monitoring of the worldwide average sulphur content of marine fuel oils showed that, the average sulphur content of residual fuel oil worldwide in 2011 was 2.65% m/m, and the average sulphur content of distillate fuel oil was 0.14% m/m, the discussion at that time did not lead to any substantial actions, but MEPC agreed to revisit the matter at its meeting in 2014.

MEPC 66 held in March 2014 further discussed this issue upon the request from the shipping industry. MEPC recognized the needs and importance of conducting an early review of fuel availability, and agreed to establish a correspondence group to develop the methodology to determine the availability of marine fuel oil to meet with the 0.5% m/m limit in 2020. MEPC further agreed to discuss the terms of reference for a preliminary study following the consideration of the report of the correspondence group at its next meeting in late 2014.

The reduction of NO_X emissions could be achieved by applying various abatement technologies, such as selective catalytic reduction (SCR), exhaust gas recirculation (EGR) and natural gas fuelled engines (LNG). However, the implementation date of Tier III limit in ECAs remains an increasing concern among State Parties and the shipping industry. As discussed in the previous paragraphs, MEPC should complete a review of the status of the technological developments to comply with Tier III limit in ECAs no later than 2013. Though MEPC 65 held in May 2013 has approved an amendment to postpone the Tier III limit in ECAs from January 2016 to January 2021, MEPC 66 held in March 2014 reopened the discussion on this issue upon the proposal from some State Parties.

The core of the debate was the availability of NO_X reduction technologies for marine diesel engines to comply with Tier III standards in ECAs from 2016 and if the application of these standards should be postponed. As the result of deliberations, MEPC 66 finally adopted amendments to NO_X regulations of Annex VI concerning the implementation date of Tier III standards. According to the amendments, the Tier III limits are applicable to marine diesel engines that are installed on board ships or after 1

January 2016 and which operate in the North America and United States Caribbean NO_X ECAs. Further, the Tier III limits are not applicable to marine diesel engines installed on board ships constructed prior to 1 January 2021 of less than 500 gross tonnage and of 24 meters or over in length. These amendments will take effect on 1 September 2015.

Needless to say, shipping is of utmost importance to the social and economic development of the entire world. Shipping is not a major contributor to the air pollution in terms of the volume of freight and number of passengers that it carries, but the prevention and reduction of air pollutants from ships is desirable. The regulatory framework of MARPOL Annex VI adopted by IMO to regulate SO_X, NO_X and PM emissions is commendable, as it provides a global level playing field for Administrations, shipping companies, the refinery sector and engine manufacturers to reduce harmful emissions from ships. The adoption of regulations is only the first step, the improvements of shipping in its environmental performance lies to a large extent in the effective implementation of those regulations by all concerned. IMO will through its MEPC keep under review the implementation of these control measures to ensure achieving the reduction of exhaust harmful emissions from ships globally.

Chapter 6 Existing Technical, Operational and Economic Measures

To reduce ship-source air pollutions, different technical and operational measures are feasible to prevent and control harmful emissions from ships. Not each and every of these technologies has been fully developed and available to be applied on a large scale, some of which need considerable investment or have practical barriers. Economic measures to address ships' harmful emissions are also applied at regional and national levels to provide incentives to ships to voluntarily reduce emissions. This Chapter will mainly discuss various emission reduction methods and their reduction potentials on the basis of the relevant literatures and studies.

6.1 Technologies to Reduce SO_X Emissions

It is known that two major methods to reduce SO_X emissions are to switch the use of marine fuels with high sulphur content to that with low sulphur content, and the application of seawater scrubbing technology.

SO_X emissions from ships, mainly SO_2 gases are generated from the sulphur in marine fuels during the engine combustion process, therefore the amount of SO_2 depends on the sulphur content of the fuel used on board, and furthermore a fraction of SO_2 becomes SO_3. (Wahlström, 2006). Typically, the amount of SO_3 is 5% of the amount of SO_2 and SO_3 (Wärtsilä, 2004). SO_3 can also form sulphate particulate matter emissions. (Flagan and Seinfeld, 1998)

6.1.1 low sulphur fuels

It is recognized that the easiest and cheapest way of reducing SO_2 emission is to use marine fuel with lower sulphur content. Low-sulphur heavy fuel oil (HFO) has higher quality and because of that it causes less wear on the machinery and needs less lubricating oil and maintenance. (Wahlström, 2006) That makes the engine run smoother and reduces the risk of operating problems. In addition, the use of low-sulphur fuels has a decreasing effect on PM emissions. (EEB et al., 2004) A switch to the low-sulphur fuel does not require any engine modifications (EEB et al., 2004) However, some attention should be given to the cylinder lubricating oil grade and feed rate as well as to the jacket cooling water temperatures. Some modifications are also needed to the fuel storage and handling system on board if several grades of heavy fuel oil are used since the different grades can be incompatible. The different fuel oil grades may also require use of different lubricating oil grades and the storage and handling of lubricating oils are also important in that respect. (Schmid and Weisser, 2005)

The average sulphur content in marine HFO is 2.65% (IMO, 2011). According to a study from Swedish None governmental Organization (NGO) Secretariat on Acid Rain, a lowering of the sulphur content to 0.5% would reduce SO_2 emission from international shipping around Europe by more than three quarters by 2020. (Ägren, 2005b) A switch from fuels with sulphur content of 1.5% would decrease PM emissions by 18% and a switch to fuel with sulphur content of 0.5% would decrease PM emissions by more than 20%. (Ritchie et al., 2005a) This study also showed that the benefits of using low sulphur fuel would be significantly greater than the costs. (Wahlström, 2006)

The growing demand of low sulphur HFO could be met by different methods. According to the study by European Environmental Bureau in 2004, the cheapest option is re-blending, which could make considerable amount of HFO with 1.5% sulphur content or less, the cost of this option is 10-16 Euros (approx. 14-22 USD) per ton. However, the HFO with less than 0.5% sulphur content could not be delivered with this method. The second option is the processing of low sulphur crude oils. The estimated cost of this option is 40-45 Euros (approx. 57-64 USD) per ton. The most expensive option is desulphurization of the HFO, which requires new investments in refinery desulphurization and the estimated cost would be 50-90 Euros (approx. 71-128 USD) per ton. (EEB et al., 2004)

6.1.2 seawater scrubbing technology

SO_2 concentration in exhaust gases can also be reduced by using seawater scrubbing technology. The method is dependent on the presence of alkaline HCO_3 and SO_4 compounds in the seawater. The alkaline compounds neutralize SO_X in the scrubber and they are transferred to the water in the form of sulphates. (Trozzi and Vaccaro, 1998) Then the water is filtered to remove particles and filtered water is recirculated back into the sea (EEB et al., 2004)

In theory the scrubber can reduce the SO_2 emissions to virtually zero and simultaneously reduce PM emissions significantly. (MES, 2005a) Relevant studies showed that SO_2 emissions can be reduced up to 95% and PM emissions can be reduced about 85% by using scrubbers. (EEB et al., 2004) Uncertainties on this method are the possible impact of the discharged scrubbing water to the sea. According to the experienced gained from the first prototype of the scrubbing system installed on the ferry *M/S Kronprins Harald* in 1991, the amount of sulphur discharged with the scrubbing water to the sea is insignificant compared to the amount of sulphate that seawater naturally contains. (Trozzi and Vaccaro, 1998)

As discussed in the previous Chapter, regulation 4 of revised MARPOL Annex VI provides possibility to the Administration for permitting the use of alternative reduction methods by ships. MEPC has also developed and adopted the Guidelines for exhaust gas cleaning systems. It is expected that scrubbers will be widely used by ships to reduce SO_X emissions.

6.2 Technologies to Reduce NO_X Emissions

For the abatement of NO_X emissions, the most promising methods are internal engine modifications, water injection techniques and exhaust gas recirculation (EGR) and selective catalytic reduction (SCR) systems. (Wahlström, 2006)

NO_X emissions consist of NO and NO_2. Nitrogen and oxygen are converted to NO_X through a complex process comprising hundreds of different chemical reactions and many intermediate products. The main source of nitrogen is the engine's intake air. Some fuels also contain nitrogen which may react with oxygen and form NO_X. NO is formed first and a part of it converts to NO_2 later in the process during expansion and in the exhaust process. (Wärtsilä, 2004; Young, 2006) The amount of NO_X formed depends on the combustion temperature, premixing of fuel and air and duration of the fuel in the cylinder. (Wärtsilä, 2004) The temperature control is an essential means of NO_X reduction. (Young, 2006)

6.2.1 internal engine modifications

This method is mainly about the improvement of combustion efficiency to reduce emissions in the combustion process. Various means can be used to decrease emissions by modifying the engines, which aim to control the NO_X emissions by lowering peak temperature and pressure in the cylinder. Engine manufacturers usually use a combination of several engine modification techniques to limit the emissions from diesel engines. (de Jonge et al., 2005)

Those techniques used to modify the engines include combustion optimization, fuel injection optimization, common rail technology, turbo-charging and charge-air cooling as well as lubrication technology. The engine manufacturers use different combination of these techniques to meet the current IMO emission limits. The most common combination used is increased compression ratio, adapted fuel injection, valve timing and different nozzles. (EPA, 2003) It is estimated that the 30-40% of NOX reduction can be achieved with the use of all these different combinations. (de Jonge et al., 2005)

6.2.2 engine process modifications

The engine process modification technology would achieve better reductions than those would be obtained by applying internal engine modifications. Engine process modifications mean changing the engine process by introducing new substances to the combustion process. These substances include water, urea or recycled exhaust gases. (Wahlström, 2006)

Addition of water to the combustion process is a promising approach for NO_X reduction. There are many techniques based on water injection to reduce NO_X emissions. (Wahlström, 2006) They all take advantage of water's ability to lower the peak temperatures in the combustion chamber and hence reduce the NO_X formation. (Wärtsilä, 2003) These techniques are direct water injection, emulsified fuel and humid air motor. The application of these techniques would at least reduce 20% NO_X emissions, and some even would achieve an 80% reduction rate.

The exhaust gas recirculation (EGR) system is a promising reduction method of the engine process modification technology. Some studies showed that the reduction rate by applying this method would achieve at least 35% reduction. However, the major problem in using EGR is the difficulty of removing all the particulate matters before the exhaust gas enters the combustion chamber. (Wahlström, 2006) Furthermore, the use of EGR may also accelerate the deterioration and wear of the combustion chamber. (de Jonge et al., 2005; Klokk, 1995) The EGR technology needs improvements before being widely used to reduce NO_X emissions.

6.2.3 selective catalytic reduction (SCR)

The SCR is a technique to remove NO_X from exhaust gases. It is an add-on system meaning that it does not interfere with the basic engine design and is not dependent on the engine manufacturers. (Wärtsilä, 2003; de Jonge et al., 2005) The reduction of NO_X emissions in the SCR system is more than 90%. (EEB, et al., 2004) As an after treatment technology, the effectiveness of SCR will vary depending on different factors. The disadvantage of the SCR method is that it needs huge investment, the volume of the system is equal with the size of engines and it consumes lots of urea which is needed to be stored on board and handled by ship crew. (Klokk, 1995)

To achieve high reduction rates, the size of the SCR system must be increased and more complicated premixing and injection systems are needed. (Wärtsilä, 2003) The SCR system is currently considered as the most promising method to reduce NO_X emissions, and it is currently a well-proven technology with over 500 applications in the marine section in 2013. (Alyson Azzara et al., 2014) However, concerns are also expressed with respect to the catalyst and other neutralization agent to be used, the issue in relation to the supply and on board storage of urea, as well as the capital and operational cost required for the application of such technology etc.

6.2.4 alternative diesel fuels

Diesel fuel is the most common fuel in the compression ignition engines. (Wahlström, 2006) Alternative fuels to replace diesel have been considered for the purpose to reduce NO_X emissions. These alternative fuels are primarily natural gas, hydrogen and bio-fuels. Because the world's crude oil reserves are still large and changing the infrastructure is expensive, the replacement of diesel fuel will probably be slow. (Karila et al., 2004)

Bio-fuels such as palm oil, coconut oil and soy oil could be used in small diesel engines, but for the marine applications they are still expensive. (Wahlström, 2006) Some pilot projects have been launched to switch the use of heavy fuel oil to liquefied natural gas (LNG) to enable the lower NO_X emissions. Despite of the significant NO_X reduction rate achieved by using LNG, the wide use of LNG would take some time before the associated technical issues could be properly solved.

6.2.5 shore-side power

This method is mainly used to reduce the air pollutants by ships when they are staying in ports and using their auxiliary engines to produce electricity needed on board. This method requires the investment of infrastructure and provision of power by ports. Some ports such as ports of Gothenburg, Seebrucke, Seattle and Los Angeles have used the method of providing shore-side electricity. The experience showed that this method is more economical than using low sulphur fuel for ships as far as the reduction is concerned. (Wahlström, 2006) However, this method is also constrained by the infrastructure development of the coast States as well as the capacity to meet the need of vessels.

The table 6.1 is a summary of major technologies for exhaust gases reductions.

Table 6.1. Major technologies and their reduction potentials (*CNSS, 2011*)

Options	Gases aim to reduce	SO_X	NO_X	PM
	SO_X			
compliant fuels	low sulphur fuel (2.65% to 0.5% m/m)	40%-80%	/	20%
alternative method	scrubber	90%-95%	/	80%-85%
	NO_X			
water addition	direct water injection	/	max.60%	max.50%
	exhaust gas recirculation (EGR)	/	20%-85%	/
	humid air motors	/	20%-80%	/
	combustion air saturation system	/	30%-60%	/
	water in fuel (e.g. 20% emulsion)	/	20%	40%-60%
engine modification	internal engine modification	/		
	- slide valves	/	20%	probably
	- advanced measures	/	30%-40%	probably
after treatment	selective catalytic reduction (SCR)	/	90%-99%	25%-40%
	SO_X and NO_X			
	LNG	90%-100%	60%	72%
	shore-side power	90%	90%	90%

In addition to the above technologies, efforts have also been made to optimize ships' design and operation with an aim to reduce exhaust gases emissions by ships. It is believed that with the advancement of technologies, more and more methods will become available for ships to control and reduce air emissions.

6.3 Economic Schemes on Ship Emissions Reduction

In addition to the technical measures illustrated in previous paragraphs, economic schemes are also considered to be feasible tools to address SO_X and NO_X emissions from ships.

6.3.1 overview of possible economic schemes

In accordance with the study conducted by NERA in 2005, four economic schemes could be potentially applicable to reduce emissions from ships.

The first scheme is the *credit-based trading approach*. This approach is based on "emission credits" which are tradable both within the maritime sector and out of the sector. The tradable emission credits will provide incentives to shipping companies to voluntarily reduce emissions and trade off their surplus emission credits either to other shipping companies or to any other land-based sectors which are also participating in such a scheme. There are several successful examples of applying this approach to control the emissions, mainly for emissions from land-based sources as well as for greenhouse gas emission reduction. However, there are also challenges to implement this scheme, among which the determination of the emission baseline is a critical issue; furthermore, the effective monitoring and reporting procedure is also important for the application of this scheme.

The second scheme is the *Consortium benchmarking approach*. Under this scheme, ships would have the option of participating in a Consortium that would voluntarily commit to achieving an average emissions rate, known as the benchmark. (NERA, 2005) Unlike the credit-based trading approach, the management of this scheme is mainly in the hand of the Consortium; however, the setting of the benchmark is also vital to the effective application of this scheme. It is important that members participating in the Consortium would be voluntarily bound by agreements reached among themselves and as well as with competent authorities that would oblige them to achieve a collective emission rate. Some enforcement techniques would be needed in order to effectively apply this scheme. (NERA, 2005)

The third scheme is the *environmentally differentiated charges approach*. It is the port under this scheme that plays a key role to impose differentiated port dues and other infrastructure-related charges to ships calling at it on the basis of its environmental criteria. A number of European ports have applied this approach to ships visiting them, and the reduction outcomes are considerable. It is important for ports that apply this approach to set up practical parameters to measure the environmental-friendliness of ships as well as to provide economic incentives to encourage ships to take positive measures to reduce emissions. Main concerns for the application of this scheme include possible unfair competitions among ports in the same region, negotiation of differentiated levels of dues and other charges.

The last scheme is the *environmental subsidy approach*. This scheme requires financial support by the government to encourage ships to take measures for reductions. This scheme is often supplementary to policy measures or other reduction programs adopted by the government. The financial support could take the form of grants, low-interest loans, favorable tax treatment and other financial assistance. (NERA, 2005) The challenges involved in the application of this approach include the funding as well as the determination of scope of ships eligible for the subsidies. The experience of applying this scheme has shown that the subsidy program applied in combination with other measures would be desirable in order to achieve an effective reduction.

6.3.2 application of economic schemes

Despite of the complexity of applying economic schemes for reduction, some European countries have taken initiatives to use the approach of environmentally differentiated charges to control and reduce emissions from ships that visit their ports.

In 1996, a Tripartite Agreement was reached among the Swedish Maritime Administration, the Swedish Port and Stevedores Association and the Swedish Shipowners' Association to use differentiated fairway and harbor dues to reduce emissions of NO_X and sulphur by 75% within five years. According to this Agreement, ships calling at Swedish ports, irrespective of flag, should reduce emissions of NO_X by installing SCR or other abatement technologies, and shifting to low sulphur fuel oil to reduce SO_X. (Kågeson, 1999) To encourage the emission reduction by ships, a discounted fairway and port dues are granted on the basis of the sulphur content of the fuel oil that ships use, and the NO_X emissions measured in grams per kWh.

The Norwegian government launched an environmentally differentiated tonnage tax in 2000. A Ship Environment Index System comprising of seven environmental parameters, including SO_X and NO_X, is used to calculate the differentiated tonnage tax for Norwegian ships. Different types of ships are measured to win credits in terms of SO_X and NO_X emission reductions to get favorable tonnage tax. However, the reduction effectiveness of scheme is limited by only applying to Norwegian ships, the further improvement is needed to cover foreign flagged ships in order to achieve a better reduction rate.

At an international level, the Green Award Foundation launched a green ship certification program to award ships with high safety and environment standards. This program involves various types of ships and incentive providers, mainly ports. Ships with certificates issued under this program will receive favorable port dues granted by participating ports. Green Award certificates need to be renewed every three years. So far ships that participate in this program cover oil and chemical tankers, bulk carriers, container ships and LNG ships; participating ports are also located in Europe, North America and Oceania.

As discussed in this Chapter, there are a number of existing emission abatement technologies which have been proven for application in reducing SO_X and NO_X emissions by ships. The most mature and common technologies are the use of low sulphur fuel, SCR and shore side power. Others that are promising but require further development include EGR, internal engine measures and seawater scrubbing. It is anticipated that, with the development of these technologies and introduction of new technologies, the IMO emission reduction standards would be met and the reduction rate would be achieved. As far as economic measures are concerned, though the complexities of their application are recognized, various economic tools are considered to be the effective complement to technical and operational measures, therefore they also merit further development.

Chapter 7 EU Actions

The maritime transport sector contributes significantly to the economy of Europe. It not only carries international transport of goods between the European Union (EU) member States and the rest of the world, but also it plays a vital role of transporting goods within EU. The EU has always been pioneering in taking measures to prevent and reduce exhaust gas emissions from shipping. The regulatory measures adopted by EU could be dated back to late 1990s, which also to some extent contributed the development and adoption of the 1997 Protocol to MARPOL by IMO. 25 out of 27 EU member States are MARPOL Annex VI parties, the effective implementation of Annex VI regulations are of vital importance to the environmental protection and human health of EU. This Chapter will mainly examine the action taken by EU collectively and by its member States individually to address air pollution from ships.

7.1 Overview of the EU Regulatory Measures

As early as late 1980s, the EU has developed several legal instruments to deal with SO_X and NO_X emissions from land-based sources. These measures have yielded tangible results as far as the control and reduction of harmful emissions from shore side is concerned. The attention was not shifted to the shipping sector until late 1990s when it was aware that air pollutants from ships would cause serious problems that affect the marine environment and human health. In order to develop a strategy to protect and conserve the marine environment, a number of Directives were adopted to commit the European communities to take actions on ship emissions.

In December 1994, the European Parliament and the Council adopted Directive 94/63/EC to control VOC emissions resulting from the storage of petrol and its distribution from terminals to service stations. Directive 1999/32/EC adopted in April 1999 deals with the reduction in the sulphur content of certain liquid fuels which sets sulphur limits for marine distillate oil used in EU waters. This Directive was subsequently amended by Directives 2005/33/EC and 2012/33/EU to keep consistent with revised IMO Annex VI SO_X regulations. In October 2001, the European Parliament and the Council adopted Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants. This Directive mainly deals with emissions irrespective pollution sources in the territory of EU member States and their EEZs which are cause of acidification, eutrophication and tropospheric ozone formation. The national ceilings on these emissions are required to be introduced in EU countries by the end of 2010.

With respect to the reduction of NO_X, CO and PM emissions from engines, the European Parliament and the Council adopted Directive 97/68/EC in December 1997 to provide emission standards and type-approval procedures for engines to be installed in non-road mobile machinery. This Directive was later amended by Directive 2004/26/EC which provides stricter emission limits for NO_X and PM and also extends the scope of application to inland waterway vessels and railways. To ensure the safety and quality of marine equipment carried on board ships, Directive 96/98/EC was adopted in December 1996 to regulate marine equipment on board European ships. This Directive was further amended by Directive 2012/32/EU. These requirements are beneficial toward addressing atmospheric and marine pollution from ships.

In addition to these Directives, the EU also adopted a Clean Air for Europe (CAFE) Program to establish a long-term and integrated framework to address air pollution and prevent its adverse impact on the environment and human health.

7.2 EU Strategies to Reduce Atmospheric Emissions from Seagoing Ships

With the increasing concern over air pollution from ships, the European Commission in 2002 adopted an "EU Strategy to reduce emissions from seagoing ships" with an aim to tackle with the impact of acidification, ground-level ozone, eutrophication, human health problems, climate change and ozone depletion from a broad perspective. The objectives of the strategy are to reduce ships' emissions of SO_2, NO_X, PM, VOC, ozone-depleting substance and CO_2 from all ships operating in EU waters. The European Commission also adopted the "Thematic strategy on air pollution" which targets the 81%

reduction of SO_2 and 60% reduction of NO_X by 2020. The emission control costs are estimated to be reduced by between 23% and 57% if ships were included in the strategic scheme. (Cofala et al. 2007)

In order to achieve the objectives of these strategies, the EU as a whole has contributed considerably to the introduction and implementation of IMO regulations on reduction of SO_X and NO_X; furthermore at regional and national levels, EU member States are required to regulate their ships to control the sulphur content of the marine fuel and use the MARPOL Annex VI compliant fuel. The EU has plan to extend Emission Control Areas to cover all EU waters and make combined SO_X and NO_X ECAs for a better emission reduction rate. The existing SO_X ECAs within EU waters are the Baltic Sea and the North Sea, and there is currently no NO_X ECA in EU; therefore it is planned to expand ECAs to cover the North East Atlantic, the Mediterranean, the Black Sea, and the Irish Sea, and make them subject to both the SO_X and NO_X ECA standards. EU member States are also required to set up mandatory NO_X emission standards for all ships entering EU ports to deal with NO_X emissions of the existing and new ships; and to establish effective monitoring measures to ensure the compliance and enforcement of relevant standards, not only by seagoing ships, but also by marine fuel traders.

As a complement to the technical and operational regulations, the EU has also required its member States to adopt market-based instruments to apply "polluters pay" principle for the shipping industry. This would be achieved through the introduction of charges corresponding to the amount of pollutants that ships emitted. In the *European Commission's White Paper on the Common Transport Policy* (CEC, 2001c), it is proposed to develop EU-wide charging systems for the infrastructure used by the maritime sector and the application of fair and efficient pricing principles that internalize external costs applied to all transport modes. It is expected that these economic instruments could provide incentives and facilitate the use of cleaner fuels and the investment in technologies on emission reduction.

7.3 Specific Measures on SO_X and NO_X emission reduction

As an integral part of these strategies, the EU adopted Directives 1999/32/EC and 2005/33/EC to regulate the sulphur content of fuels used on board EU ships. These Directives were recently amended by Directive 2012/33/EU where the latest IMO mandatory requirements on SO_X reduction are transposed into EU law. EU member States are allowed to provide aid to ship operators as long as such aid measures are compatible with relevant requirements. The European Commission is also required to make full use of economic instruments that are already available to promote the development of new and alternative technologies to reduce ships' emissions.

According to the requirements in Directive 2012/33/EU, member States should amend their existing law on marine fuels quality by 18 June 2014, by which legal certainty is provided for investment by ship industry, port operators and refinery industry. The Directive also requires that from 2015 onwards, the sulphur content of fuel used by ships operating in the Baltic Sea and the North Sea including the English Channel should be no more than 0.1%; and from 2020 onwards, ships operating in all other European waters should use fuel with sulphur content of 0.5% or less.

Unlike the legislation on SO_X emission reduction, there are currently no binding regulations specifically on ships' NO_X emission reduction in EU, but EU member States are expected to apply IMO standards (Tier I, II and III) to all ships entering European ports. From the industry's side, the mandatory IMO NO_X standards provide incentives to engine manufacturers in Europe to research and develop techniques to comply with those standards.

As discussed in the previous Chapter, the marine SCR technology is presently considered mature and feasible to control and reduce the NO_X emission from ships. Many European manufacturers have invested to pursue this technology for more than 20 years, and have proved it to be capable of meeting current and future IMO NO_X emission reduction requirements. As more and more marine engines using SCR technology are installed on board ships, those manufacturers are having started the certification of these engines. In this connection, the effective date as required in MARPOL Annex VI on NO_X Tier III standards is important to provide certainties to engine manufacturers and to ships having installed such engines. The postpone of effective date of Tier III standard for NO_X ECAs at MEPC 65 raised serious concern in EU and the industry; although this decision was finally compromised at MEPC 66 by retaining the original effective date 2016 for existing NO_X ECAs, and leaving new NO_X ECAs undecided until the time when they are designated, it could be expected that the EU and its industry will make continuous efforts to promote the implementation of Tier III standards in order to protect the air quality and human health in Europe.

As far as the market-based measures are concerned, though the EU is always favorable for applying economic instruments to reduce emissions from ships, and its Emissions Trading System (ETS) has also been proven successful in controlling emissions from land-based sources as well as for the aviation industry, the outcomes of relevant studies showed that it is not legally possible to deviate from or offset the MARPOL Annex VI requirements (applicable to individual ships) through an EU ETS unless such a possibility was created within the IMO framework.(VITO 2010) This is mainly because of the peculiar characters of the shipping industry, therefore, further efforts will be needed to facilitate the development of economic instruments at an international level to that end.

7.4 Economic Measures by Selected EU member States

The market-based measures to be implemented by EU as a whole may take some time, but some States have already adopted economic instruments for the abatement of SO_X and NO_X emissions from ships visiting their ports. These measures have been briefly discussed in the previous Chapter. The following paragraphs will further examine the effect of these measures and their improvement for broad applications.

As previously discussed, since 1996, the differentiated fairway and port dues have been applied by Swedish Maritime Administration to provide incentives to visiting ships to reduce emissions by using low sulphur fuels and installing SCR or other abatement technologies. The fairway dues are related to the different types of ships and their gross tonnage and the amount of cargo carried on board. The port dues are differentiated among participating Swedish ports. The discounts of fairway and port dues are subject to the quality of the marine fuel that ships use and the NO_X emission measured in grams per kWh. Although these measures have provided reasonably adequate incentives to ship owners to switch to green, the discounts do not reflect real emissions. (Kågeson et al., 2009) Even if there might in most circumstances be a relatively accurate relationship between the gross tonnage and engine output, neither the fairway due itself nor the discount take into account the distance that ships travelled. (Kågeson et al., 2009)

The result of applying differentiated fairway and port dues in Sweden has shown that most frequent visiting ships choose to use low sulphur fuel in the Baltic and North Seas to gain a discount; and relevant studies also revealed that it was economically advantageous for frequent visiting ships to install SCR technology to get a NO_X emission reduction discount. The Swedish differentiated fairway and port dues is an existing market-based instrument with a potential to influence ship owners' decision on fuel oil sulphur content and NO_X abatement technology. (Kågeson et al., 2009) Its success is also attributed to the geographic location of Sweden and a wide engagement of Swedish ports in this program.

Like the Swedish government, since 2000, the Norwegian Maritime Authority has also employed an economic instrument to control harmful emissions from ships. This instrument was based on an environmentally differentiated tonnage tax, which targeted the SO_X, NO_X and CO_2 emissions from Norwegian ships. However, this measure was considered very modest because ships of less than 1,000 net tonnage or engaged in international traffic would be exempted from application. The Finnish port of Mariehamn in Åland also use a differentiated port dues relating to ships' emissions, but most participating ships are ferries operating between Finland and Sweden. The Norwegian and Finnish economic schemes are not as effective as the Swedish one.

It can be found from the previous discussions that the effective employment of economic instruments relies on various factors. The existing Swedish system has achieved a desirable effect on ships frequently call at its ports, but it provides no incentives for other rarely calling ships that operate in

EU waters. In order to engage ships in shifting to low sulphur fuels and installing NO_X abatement technology, a common system of economic incentives will be needed so that all States and stakeholders will be involved to jointly achieve the goal of reducing SO_X and NO_X emissions from ships.

In recognizing the serious impact of air pollution on the environment and human health, the EU has acted on various fronts to reduce harmful emissions, and the maritime sector is one of its priorities in that respect. Prior to the entry-into-force of MARPOL Annex VI, the EU has already taken more stringent rules at regional level to control SO_X and NO_X emissions from ships, at the same, the EU and its member States have also studied different options of economic instruments and applied a few at national level. As IMO phases in stricter mandatory reduction standards at international level, the EU has also incorporated these standards into EU law and promoted their implementation globally. It is envisaged that the EU will continue its efforts to ensure an effective enforcement of IMO standards, and take initiatives to develop universally applicable economic incentives to complement the existing technical and operational measures addressing harmful emissions from ships.

Chapter 8 Policy Tools and Best Practices by Selected APEC Member Economies

8.1 Policy Tools and Best Practices of the United States of America

8.1.1 Clean Air Action Plan (CAAP)

The port of Long Beach launched a Clean Air Action Plan (CAAP) with the following goals:

- To minimize health risk from port operations;
- To build up existing programs;
- To set consistent standards;
- To enable port development.

Collaboration

- Ground-breaking plan to significantly reduce air pollution and health risk;
- Strategies targeting reductions from all port source;
- Developed jointly with Port of LA, in cooperation with Environmental Protection Agency (EPA), California Air Resources Board (CARB) and Air Quality Management District(AQMD).

Implementation

The plan is aimed to reduce air pollution and reduce health risk 85% by 2020. As figure 8.1 shows, the sources of Diesel Emissions, the strategies adopted by the plan mainly includes all categories of emission source, ranging from ships, harbor craft, trains, to trucks and cargo handling equipment.

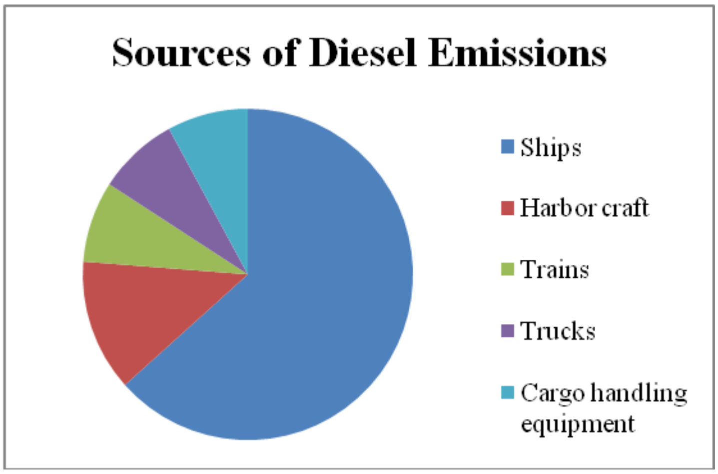

Figure 8.1. Sources of diesel emission

(1) Vessel strategies

For sea-going vessels, the following measures were taken to reduce emission: Green Flag Vessel Speed Reduction Program; Shore-to-ship electricity; Low-sulfur diesel fuels; NO_X and PM controls. For Harbor craft, such measures as re-power or replace vessels were adopted.

(2) Clean trucks

A total number of 11,000 trucks are registered as clean trucks, more than 700 of which are LNG trucks. Consequently, truck related pollution was reduced by more than 90% in three years.

(3) Switcher locomotives

The port upgraded its fleet to Tier II engines in 2008 and to Tier III-plus in 2011, thus reduction of Diesel PM and NO_X is 95% and 72% respectively.

(4) Technology advancement

An advisory committee was established and such technology advancement was highlighted as hybrid tug boats, battery-powered trucks, fuel-cell hybrid trucks and alternative vessel strategies.

(5) Tracking, monitoring, and reporting

- Expand port-area real time air monitoring network;
- Emissions inventory-regular updates;
- Monitor progress on Clean Air Action Plan;
- Report progress on Clean Air Action Plan.

8.1.2 shore power at the port of Long Beach

As the second largest container port in USA, the port of Long Beach handles over 7 million containers a year, thus bring a mass of harmful exhaust emissions. To reduce the impacts of those emissions to the community health, port of Long Beach adopted a great variety of measures including Green Port Policy, Ship speed Reduction, Clean Air Action Plan and Clean Truck.

Especially, a report on the emission by ship mode in 2011 showed the emission ratio by ship on Transit, maneuvering, anchorage and berth is 43%, 7%, 10%, 41% respectively. Therefore, Shore Power is developed including Pier G (first berth in 2008), Pier T (BP world's only shore powered oil facility in 2009) and Pier C (two berths in 2011). The ships on berth are plugged into the electrical grid and the auxiliary engines were turned off, and thus, emissions were reduced significantly. In addition, California has issued a regulation on the shore power, and the ratio of the visit fleet utilizing the shore power in the future is listed in table 8.1.

Table 8.1. Ratio of the visit fleet utilizing the shore power in the future

	Ratio of fleet calls must use shore power	Ratio of emission reduced by fleet
2014-2016	50%	50%
2017-2019	70%	70%
2020+	80%	80%

In terms of building the shore power for the future some principles are proposed:

(1) More investment, careful sequencing and substantial industry cooperation.

(2) International shore power standard.

- Three standards organizations including ISO, IEC, IEEE.
- High voltage shore connection system.
- Covers system requirements, ship connections, verification and testing.

(3) System design

- 6,600 volts, 3 phases, 60Hz.
- Provide7.5MVA of power enough for fully loaded ship at max demand.

Comparison is made on projected NO_X and Diesel PM emissions between with and without the proposed regulation in figure 8.2 and figure 8.3. (Source: California Air Resource Board, 2007)

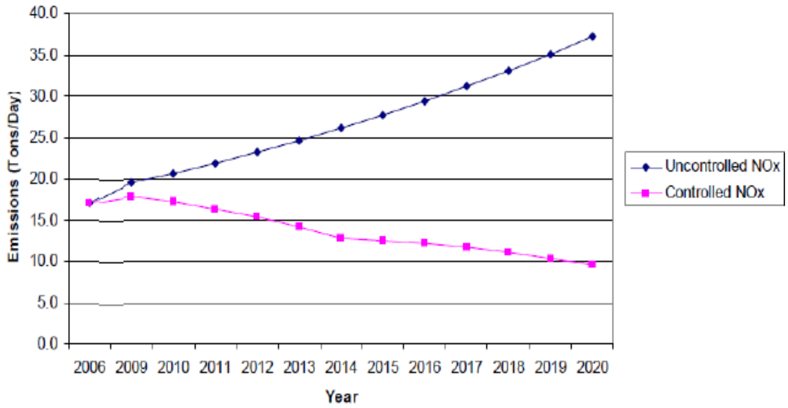

Figure 8.2. Projected NO_X emissions with and without the proposed regulation

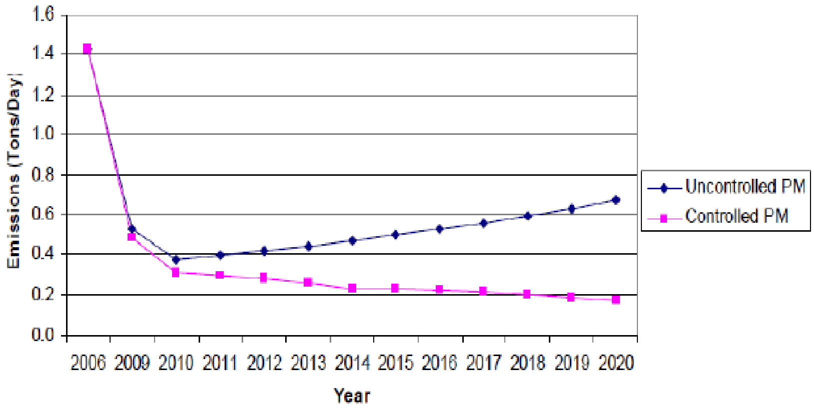

Figure 8.3. Projected diesel PM emissions with and without the proposed regulation

8.2 Policy Tools and Best Practices of Canada

8.2.1 new regulations for vessel air emissions, ship to ship transfers of oil and grey-water (2013)

The Regulations Amending the Vessel Pollution and Dangerous Chemicals Regulations (the Amendments) were published in Part II of the Canada Gazette on May 8, 2013. The Amendments implement standards for the North American Emission Control Area (NA-ECA), energy efficiency of vessels and a regime for Canadian vessels in the Great Lakes and St. Lawrence waters. The Amendments constitute the New Regulations for Vessel Air Emissions, Ship to Ship Transfers of Oil and Grey-Water (2013) and also update standards for ship to ship transfers of oil at sea and new minimal standards for managing grey water.

(1) Sulphur oxides

For vessels inside the NA-ECA and throughout Canadian waters south of 60°N, the Amendments set a limit of 1.00% on the sulphur content of marine fuel. This will be followed by a 0.10% limit after January 1, 2015.

In waters outside of the NA-ECA, North of 60°N and including all of Hudson’s Bay, James Bay and Ungava Bay, the Amendments set the global standards under MARPOL for controlling sulphur oxides, which currently comprises a 3.50% limit on the sulphur content of marine fuel and after January 1, 2020, the Amendments set the standard to 0.50%.

In the event IMO decides to defer the 0.50% standard to January 1, 2025, the Regulations will be amended at that time. Vessels over 400 gross tonnages are already required by the Regulations to carry bunker delivery notes, which stipulate the sulphur content of fuel delivered to the vessel.

In the event a vessel destined to a Canadian port has not been able to obtain compliant fuel, the Amendments require the vessel to report its situation to Transport Canada. A vessel destined to a port either in the United States or France (St. Pierre and Miquelon) is required to report to the Administrations. In the case of a vessel only transiting Canadian jurisdiction, it is not required to report to Transport Canada.

For Canadian vessels voyaging in the Great Lakes and St Lawrence waters, the Amendments provide a fleet averaging regime, where compliance with the sulphur content standards is determined by the average sulphur content of all the fuel used by a firm's fleet.

(2) Nitrogen oxides

The Amendments set controls on nitrogen oxides for engines installed on vessels that have power ratings over 130 kilowatts. Beyond this, the Amendments adopt the requirements for the management of engines to limit emissions of nitrogen oxides set out in the NO_X Technical Code, 2008.

In the event a vessel undergoes a major conversion, or a new engine is installed which is substantially different from the old one, the more current standard would apply. For example, if a vessel built in 2001 undergoes a major conversion in 2014, it will then be subject to Tier II standards rather than Tier I.

(3) Smaller marine diesel engines

The Amendments set a requirement for when a vessel installs new engine for propulsion that is 7 liters or more per cylinder and under 30 liters per cylinder. On or after January 1, 2016, such an engine will need to be certified to have met either the United States Environmental Protection Agency's "Category 2" engine standards, or equivalent international standards such as those in Europe.

(4) Energy efficiency

The Amendments require all vessels to carry a Shipboard Energy Efficiency Management Plan (SEEMP). This can be a simple statement within a vessel's Safety Management System documents, or a more detailed document on its own.

The Amendments set requirements for new vessels built after June 30, 2013, that trade internationally to have calculated its Energy Efficiency Design Index (EEDI) and meet its required efficiency target set out in the July 2011 revisions to Annex VI to MARPOL. A vessel that undergoes a major convention will be subject to the standards that apply in the year of that conversion rather than the year the vessel is originally built.

The Amendments exempt from the EEDI requirements new Canadian vessels that voyage exclusively in Canadian jurisdiction or the Great Lakes. A Transport Canada technical study and found applying the EEDI to new Canadian vessels would result in higher greenhouse gas emissions. Transport Canada intends to apply this standard to new Canadian vessels once technical issues are resolved which will require two to three years.

For new Canadian vessels intended to voyage internationally, the Amendments require them to meet the relevant EEDI requirements. Compliance is demonstrated by the International Energy Efficiency Certificate.

(5) Certificates

The Regulations require all vessels over 400 gross tonnage to have an Air Pollution Prevention Certificate.

Under the Amendments, a Canadian vessel that is relying on a fleet averaging regime for compliance with standards must carry a Canadian Air Pollution Prevention Certificate. Canadian vessels that fully comply with MARPOL standards must carry the International Air Pollution Prevention Certificate and do not need to carry the Canadian certificate.

All vessels on international trade are required by the Amendments to carry an International Energy

Efficiency Certificate, which is issued based on an existing vessel having a SEEMP and a new vessel having met its EEDI target.

A new Canadian vessel that voyages only in Canada or the Great Lakes water would not be issued an International Energy Efficiency Certificate, if it does not determine its EEDI value as it is exempt. A new Canadian vessel voyaging internationally is required to have an EEDI calculated and subsequently would be issued this certificate.

(6) Equivalent measures

The Amendments allow for alternative compliance options that result in equivalent emissions to using the compliant fuel. Typically, this would be expected to be scrubbers, but can include regional fuel averaging regimes. For a Canadian vessel, an alternative compliance option must be approved through the Marine Technical Review Board. For a foreign vessel, this must be approved by the authority where it is registered (the flag State). Before a flag State grants such an approval, Canada and APEC economies that are part of emission control areas where that vessel may voyage, expect to be able to review and consent to the alternative compliance option.

(7) Ship to ship transfers of oil

For oil tankers of 150 gross tonnages or more, the amendments implement amendments to Annex I to MARPOL for new requirements for oil cargo transfers at sea that entered into force on January 1, 2011 (IMO Resolution MEPC.186 (59)).

Those oil tankers are required to keep on board a ship to ship (STS) operations Plan, if they are not alongside a wharf or quay and are engaged with another oil tanker in a transfer operation involving oil or an oily mixture in bulk. For Canadian tankers, the authorized representative is required to ensure that the Plan is implemented. For foreign tankers, this requirement is the responsibility of the master. Records required by the STS operations Plan are required to be made and kept on board for 3 years.

If the transfer operation involves a Canadian vessel and is in the territorial sea or Exclusive Economic Zone of any Party to MARPOL other than Canada, the vessel's master is required to notify the local authorities at least 48 hours prior to the operation.

If the transfer operation is in waters under Canadian jurisdiction the vessel's master is required to notify Canadian authorities at least 48 hours prior to the operation.

8.2.2 Air Action Program by the Port Metro Vancouver

The Port Metro Vancouver Air Action Program focuses on development of a data baseline, reducing emissions and tracking progress towards to goal of continuous improvement in terms of reducing emissions that contribute to air quality and climate change. The program includes initiatives being undertaken by the Port, the tenants and other industries as well as regulatory agencies, which are all helping to reduce port-related air emissions.

Marine vessels

(1) Participation in seawater scrubber feasibility and demonstration project with U.S. Environmental Protection Agency, Environment Canada, Port of Seattle etc.

(2) Shore power

A feasibility assessment for use of shore power at Port Metro Vancouver cruise ship berths has been completed, which aimed to implement shore power for cruise vessels at Canada Place by 2009. Information gathered through the Port's Differentiated Harbour Dues Program provided input to shore power assessments. Shore power infrastructure provisions that allow for future installation with minimum disruption to terminal operation have been incorporated into Centerm and Vanterm container terminals and will be installed at Deltaport's third Berth as well.

(3) Commitments from shipping lines to use cleaner fuels year-round, in port and out at sea.

(4) Implementation of the Port's Differentiated Harbour Dues Program starting April 1, 2007 that

recognizes through lower fees, vessels that reduce the air emissions. Increased awareness from program has contributed to additional commitments from shipping lines to use cleaner fuels on all calls to Port Metro Vancouver, beyond those where the harbour due rate recognition is available.

(5) Vessel Opacity Program including education of vessel operators on excessive opacity levels and follow-up with specific vessels was conducted as required.

(6) Pilot tests using West Vancouver developed fuel-borne catalyst in ocean going vessel auxiliary and main engines completed in 2005.

(7) Actively supporting federal governments:

- Ratification of MARPOL 73/78 Annex VI, Regulations for the Prevention of Air Pollution from Ships;
- Research into potential application to designate the west coast of North America as a Sulphur Emission Control Area post-ratification;
- Review of existing Annex VI requirements.

(8) Transport Canada's Pollution Prevention Guidelines for the Operation of Cruise Ships under Canadian Jurisdiction is a voluntary agreement with cruise ships to "use fuels with the lowest sulphur content available for the class of fuel that the ship's engines are designed for".

(9) Federal marine diesel fuel quality and engine emission standard improvements.

Terminals

(1) Hybrid diesel-electric power units in three rubber tired gantry (RTG) cranes were tested in 2007-8. Preliminary results showed a 74% reduction in fuel consumption.

(2) In partnership with Metro Vancouver, Environment Canada, Corporation of Delta and Tsawwassen First Nations, siting and installation of an ambient air quality monitoring station in the vicinity of Deltaport operations to ensure good air quality in Delta.

(3) 2007 terminal equipment idle reduction programs at terminals including Lynnterm operated by Western Stevedoring.

(4) Commitment from International Long-shore and Warehouse Union (ILWU) to reduce unnecessary idling of terminal equipment.

(5) Early 2007 on-road vehicle idle reduction program that included education packages sent to Port Metro Vancouver commercial tenants.

(6) On-road diesel fuel being used in off-road equipment at terminals including Deltaport, Vanterm and West Coast Reduction.

(7) Biodiesel is being used as B10-B50 at Vanterm and Deltaport container terminals.

(8)Alternating current ship-to-shore cranes, many of which regenerate energy on lowering of containers, sending it back to the electricity grid are in use at all container terminals. These cranes run on electricity, and we no longer have any diesel versions.

(9) A number of rail mounted gantries (RMG) also regenerate energy, sending it back to the grid, with the remaining RMGs expected to be converted to do so as well.

(10) Pilot test using West Vancouver developed fuel-borne catalyst in container handling equipment in 2004. Success of pilot led to catalyst's continued regular use in Vanterm terminal equipment.

(11) Federal off-road diesel fuel quality and engine emission standard improvements.

Trucking

(1) In 2005, the Port introduced a container truck licensing system (TLS) to provide for requirements to improve efficiency, safety and environmental performance of trucks accessing terminals.

(2) Introduced mandatory reservation systems and implemented extended gate hours to alleviate congestion and line ups at terminals, and reducing general roadway congestion.

(3) Radio frequency identification system pilot introduced to improve efficient flow of goods through terminals and reduce unnecessary trips.

(4) Port-targeted opacity testing and safety inspections by BC Ministry of Transportation.

(5) Truck idle reduction assessment and education program rolled out in 2006-7 developed with help from Better Environmentally Sound Transportation (BEST) and City of Vancouver that included education packages distributed to tenants and drivers.

(6) Port Metro Vancouver, through a subsidiary acted as a catalyst in development of Coast 2000 Terminals Ltd. in1999 with Fraser Group Holdings. Coast 2000 is an off-dock facility that reduces the number of empty container truck trips.

(7) Exploring short sea shipping as an alternative to reduce local/regional truck trips.

(8) Federal on-road diesel fuel quality and engine emissions standard improvements.

Innovation and collaboration

(1) Port Metro Vancouver, in partnership with the Port of Seattle and Port of Tacoma, and with support from Environment Canada, the U.S. EPA, B.C. Ministry of Environment, the Puget Sound Clean Air Agency and the Washington State Department of Ecology, developed the Northwest Ports Clean Air Strategy. The strategy includes emission reduction performance goals for port-related sources, and represents a cooperative effort amongst the three ports to improve air quality.

(2) Actively participating in the West Coast Collaborative, a partnership between all levels of government, the private sector and environmental groups along the West Coast of North America. The group focuses on reducing diesel emissions and has dedicated work groups for marine vessels/ports, trucks, rail, construction and agriculture. Port Metro Vancouver coordinated development of an online technical clearinghouse for the marine vessels/ports sector to share experience with emission reduction options and to facilitate use by others.

(3) Actively participating in the BC Marine Vessel Air Quality Work Group, whose other members include Environment Canada, Transport Canada, Ministry of Environment, Metro Vancouver, BC Ferries and the BC Chamber of Shipping among others. The group is developing emission inventories and cooperates by exchanging information and analyzing options for reducing emissions.

(4) Application of technologies to increase operational efficiency and velocity of cargo throughout the supply chain. These technologies help to identify at an early stage potential issues, and facilitate prevention of problem development.

Communication

(1) Inclusion in 2005 of a section on air quality and climate change on the Port's web site, which details initiatives to reduce emissions.

(2) Workshops with tenant environmental managers to discuss issues and opportunities, and to exchange information. December 2006 meeting dedicated to topic of air emissions.

8.2.3 shore power project of the Port Metro Vancouver

The Shore Power Technology for Ports (SPTP) program is part of the Government of Canada's ongoing efforts to limit emissions in the Canadian transportation sector and improve air quality. The SPTP program provided cost-shared funding for the deployment of marine shore power technology at Canadian ports; this technology allows ships to plug into the local electrical grid to power the vessel instead of using their auxiliary diesel engines when docked.

The Marine Shore Power Program (2007-2012) was the precursor to the SPTP program and successfully demonstrated that marine shore power technology could be implemented in Canada. Two projects were funded under the Marine Shore Power Program.

The marine shore power installations at Port Metro Vancouver's Canada Place Terminal allow properly equipped cruise ships to plug into the local electrical grid instead of operating their diesel engines to power the ships load when docked. The case study offers an overview of the project and presents results for the 2010 cruise season.

With funding from Transport Canada's Marine Shore Power Program, PMV Shore Power Project was implemented to reduce air emissions from cruise ships. The technology allows cruise ships to shut down their diesel engines while docked and use clean hydroelectricity to power onboard services instead. The major benefits include reducing fuel costs, significantly improving local air quality (Criteria Air Contaminants (CAC) emission reductions), and reducing noise.

After the completion of construction, data related to ship connection time to shore power was collected and analyzed to measure fuel consumption reductions. These fuel consumption reductions are responsible for CAC emission reductions which were calculated using Environment Canada's most recent conversion factors for the marine sector. Other benefits examined include the average cost of fuel vs. the cost of electricity to determine expected savings for ships employing shore power.

From April 2010 to October 2010, 44 connections were made at the Canada Place Terminal at PMV. These 44 connections, for a total of 268 hours provided 2,024 MWh of electricity in lieu of 476 tons of fuel, leading to a significant amounts of CAC resulting from ship idling.

Tables 8.3-8.4 summarize the ship calls and connection results for the 2010 season (April to October).

Table 8.3.-April 2010 to October 2010 Ship calls to Canada Place Terminal

Total Number of Visits	No. of Shore Power equipped Visits	Berthed Time
177	58	629.5 hours

Table 8.4.-April 2010 to October 2010 Completed connections to shore power

No. of Completed Connections	Connected time (hrs)	Electrical Consumption (MWh)	Fuel Savings (tones)
44	267.7	2,024.1	475.6

As shown above, 177 ships visited PMV's Canada Place Terminal between April 2010 and October 2010 for a total docked time of 630 hours. Of the 177 ships that called, 58 were equipped with shore power capabilities. However, scheduling and other considerations led to 44 successful connections for a total of 268 hours. On average a ship is connected to shore power for 6 hours and reduces its consumption of fuel by 10.7 tones per visit (or 1.78 tons per hour).

8.2.4 experiences conducting port emissions inventories in Canada

Port Emissions inventory history in Canada

(1) Port Metro Vancouver conducted the first Canadian port EI in 2008, for the 2005 inventory year.
This inventory focused only on land side activities.
(2) A complementary study by the BC Chamber of Shipping investigated emissions from marine sources for the 2005/2006 inventory years.
(3) A complete inventory of both land side and marine emissions was completed for the Port of Montreal in 2009, with funding from Transport Canada.
(4) Transport Canada (TC) was providing funding to industry partners through several initiatives.
• The largest program was eco-FREIGHT, which supported the transportation industry to

reduce fuel consumption and air pollution. • Port terminals in Vancouver and Montreal received funding to upgrade gantry cranes and facility locomotives, respectively, from this program. • These and other eco-FREIGHT projects demonstrated the emission reduction potential of technology improvements. • In January 2012 Transport Canada announced a new $CDN 27 million funding program for installing marine shore power (i.e., cold ironing). • However, one of the complaints from operators about these funding programs was the difficulty in meeting program requirements and consistency in the evaluation metrics.
(5) TC contracted SENES Consultants to develop a national Ports Emissions Inventory Protocol (Ports Protocol), to apply uniformly for all ports in Canada.
This protocol extended the Environmental Protection Agency(EPA)"Best Practices" document into a formal guidance document outlining scope, pollutants, boundaries, source groups, etc. (The Ports Protocol is described in more detail in the following section.)
(6) Transport Canada funded the development of a national Ports Emissions Inventory Database Model (Ports Model).
The Ports Model was an implementation of the Ports Protocol and was based on the port EI database models developed for Port Metro Vancouver and Port of Montreal. (More details are also provided on the Ports Model in the next section.)
(7) In 2010/2011, the Ports Model was used to calculate the 2009 emissions for three other Canadian ports: Hamilton, Ontario; Sept-Iles, Quebec; and Halifax, Nova Scotia.
The Ports Model was the template for the recent update of the Port Metro Vancouver (PMV) landside emissions inventory, for the 2010 calendar year. This inventory was the most detailed completed to date in Canada and included all port-related activity in the Lower Fraser Valley. In 2011, Transport Canada contracted SNC-Lavalin Environment (SLE) to conduct port EIs for all 18 Canadian Port Authorities for the 2010 inventory year. These inventory projects are ongoing and will be completed for the west coast ports in 2012 and the east in 2013.
Others: The efforts of Green Marine and Environment Canada, combined with recent port EI experiences, showed that the Ports Protocol and the Ports Model both required updating. As part of the 2010 national ports EI project, TC hired SLE to clarify and add new elements to the Ports Protocol. SLE also upgraded the Ports Model to improve the calculation methodology and simplify the data collection burden for terminals. The updated version of the Ports Model can also be used to generate EI reports suitable for submission to GM. Transport Canada will release the Ports Model to the public in 2012 so other port authorities and operators can benefit from the experience.
(8) Green Marine (GM) is a joint US-Canada initiative to implement a marine industry environmental program throughout North America.
Founded in 2007 in the Great Lakes, GM's environmental program includes certification for managing air quality by conducting an emissions inventory. GM is a stakeholder on the TC 2010 national ports EI project.
(9) The Environment Canada (EC) National Marine Inventory, completed in 2012 for the 2010 calendar year.
The inventory includes all commercial marine vessels tracked by the Canadian Coast Guard within Canada's territorial waters as well as smaller commercial crafts such as tugs and ferries. A large project advisory committee of 30 representatives from shipping associations, port authorities, provincial governments and regulatory agencies provided direction and

supporting data to better characterize the marine vessel movements and emissions. EC is also a stakeholder on the TC 2010 national ports EI project.

Canadian experiences conducting port emissions inventories

(1) Port Metro Vancouver 2010 Land-side Emissions Inventory

Port Metro Vancouver is the largest port in Canada and handles over $75 billion worth of imports and exports each year. Most PMV terminals have a water lease with the port authority but operate on a mixture of private and public land. PMV was the first port in Canada to conduct a port emissions inventory, for the 2005 inventory year, which focused on the landside activities of terminals in the Burrard Inlet and Roberts Bank in Delta. A second inventory was recently completed by SLE for the 2010 calendar year. The 2010 inventory expanded the project scope to include over 115 terminals from the Burrard Inlet, Fraser River and Roberts Bank.

The 2010 inventory used a customized version of the Transport Canada Ports Model. Four source groups were included in the inventory: Admin, Cargo-handling equipment (CHE), On-road and Rail (marine was included in the EC 2010 National Marine Inventory). Five zones in the Lower Fraser Valley where port-related activity dominated were chosen to represent the port boundary. Table 8.5 shows the results of the PMV 2010 inventory to the port boundary. Cargo-handling emissions dominated, followed by On-road.

Table 8.5. Port Metro Vancouver 2010 landside emissions, to the port boundary (tones)

Source Group	Common Air Contaminants (CACs)						
	NO_X	SO_X	CO	VOCs	PM_{10}	$PM_{2.5}$	NH_3
Admin	9.0	0.1	4.9	0.5	0.5	0.5	0.3
CHE	643.4	0.8	773.8	83.4	40.9	39.7	1.1
On-road	89.9	0.3	112.1	15.7	1.7	1.2	2.0
Rail	202.7	0.8	22.8	8.3	6.4	5.9	1.2
Total	945.0	2.0	913.5	107.9	49.5	47.3	4.5

The 2010 LEI also included forecasts out to 2025 in 5-year increments. Even though PMV throughput is expected to increase by approximately 63% by 2025, emissions of most criteria air contaminants will decrease over that period as older equipment is replaced by units with higher emission standards. In contrast, newer engines are not much more fuel efficient so emissions of greenhouse gases are expected to increase during that period.

Along with the forecasts, recent and future emission reduction initiatives were evaluated for their effect on port emissions. Some initiatives implemented by individual terminals were new gen set locomotives as well as variable-speed and hybrid cranes. At a port level, PMV introduced a truck licensing system in 2008 which prohibited older heavy duty diesel trucks from operating at PMV terminals. Taken together, these ERIs reduced emissions of all major pollutants by between 1 and 7% versus a business-as-usual case.

(2) Strategies for conducting a successful port emissions inventory

Port emission inventory projects are challenging to conduct, in large part because they remain foreign to most terminals and port authorities. Assuming a database similar to the TC Ports Model is available, and data collection is the most time-consuming component of a port EI. The data provided by port authorities and terminals for port EIs is not data they generally tabulate for other regulatory requirements so errors and misunderstandings are common.

Terminal representatives were skeptical when port EIs were first conducted in Canada; they did not understand the need and assumed the data collection was in advance of new regulations. However, greater attention towards environmental stewardship at port authorities and terminals has developed in the past 10 years so recent terminal response has been more positive. Proper terminal engagement ensures participation is high and data collection progresses smoothly. An initial engagement session is recommended where all terminals are invited to attend. In addition to describing the data collection process, the engagement session should describe the benefits of conducting a port EI such as Green Marine certification or potential fuel cost savings through ERIs.

Once data collection has begun, proper data management is critical since data will be collected from a variety of sources, including terminals, port authorities, regulators and equipment manufacturers. Medium-size and large terminals all have logs of equipment activity and some have even conducted their own emissions inventories. Most of these inventories were for greenhouse gases where simpler fuel-based emission factors can be used. To calculate CAC emissions, more details are generally required, which is often not clear to terminal representatives.

8.3 Designation of North American Emission Control Area (ECA)

As discussed in the previous Chapter, IMO has officially designated waters off North American coasts as an area in which stringent international emission standards will apply for ships. These standards will dramatically reduce air pollution from ships and deliver substantial air quality and public health benefits that extend hundreds of miles inland.

The area of the North American ECA includes waters adjacent to the Pacific coast, the Atlantic/Gulf coast and the eight main Hawaiian Islands. It extends up to 200 nautical miles from coasts of the United States, Canada and the French territories, except that it does not extend into marine areas subject to the sovereignty or jurisdiction of other States.

Ships complying with ECA standards will reduce their emissions of SO_X, NO_X and fine particulate matter (PM 2.5). In 2020, emissions from these ships operating in the ECA are expected to be reduced annually by 320,000 tons for NO_X, 90,000 tons for PM2.5, and 920,000 tons for SO_X, which is 23 percent, 74 percent, and 86 percent, respectively, below predicted levels in 2020 absent the ECA. The overall cost of the North American ECA is estimated at $3.2 billion in 2020, while its benefits are expected to include preventing as many as 14,000 premature deaths and relieving respiratory symptoms for nearly five million people each year in the U.S. and Canada. The monetized health-related benefits are estimated to be as much as $110 billion in the U.S. in 2020.

8.4 Policy tools and best practices of Singapore - Maritime Singapore Green Initiative

The Maritime Singapore Green Initiative seeks to reduce the environmental impact of shipping and related activities and to promote clean and green shipping in Singapore. It is a comprehensive initiative comprising three programmes - Green Ship Programme, Green Port Programme and Green Technology Programme.

In 2011, the Maritime and Port Authority of Singapore pledged to invest up to S$100 million over the next five years in the Maritime Singapore Green Initiative.

8.4.1 enhancements to the Maritime Singapore Green Initiative

To further encourage companies to adopt environmentally-friendly shipping practices, several enhancements to the Maritime Singapore Green Initiative were conducted in April 2013.

The Green Ship Programme will be expanded to recognize Singapore-flagged ships that adopt approved SO_X scrubber technology, which go beyond IMO emission requirements. This comprises a 25% reduction of their Initial Registration Fees and a 20% rebate on their Annual Tonnage Tax. This is in addition to the current 50% reduction on Initial Registration Fees and 20% rebate on Annual Tonnage Tax for ships that exceed the IMO Energy Efficiency Design Index. Singapore-flagged ships which adopt both energy efficient ship designs and approved SO_X scrubber technology that exceeds IMO requirements will enjoy 75% reduction of their Initial Registration Fees and 50% rebate on their Annual Tonnage Tax.

Under the Green Port Programme, the port dues reduction for sea-going vessels that burn clean fuels or use approved abatement technology throughout their entire stay in the Port of Singapore will be increased from 15% to 25%. A new tier of port dues reduction of 15% will be introduced for sea-going vessels that burn clean fuels or use approved abatement technology only while at berth.

The grant limit under the Green Technology Programme will be increased from S$2 million to S$3 million for qualifying projects that can achieve more than 10% reduction in emission levels. Table 8.7 is the details on the enhancements to the Maritime Singapore Green Initiative.

Table 8.7. Enhancements to Maritime Singapore Green Initiative

Programme	Current	Enhancements
Green Ship Programme	Singapore-flagged ships, which adopt energy efficient ship designs exceeding IMO Energy Efficiency Design Index, will enjoy: • 50% reduction of Initial Registration Fees and; • 20% rebate on Annual Tonnage Tax.	(1) Singapore-flagged ships that adopt approved SO_X scrubber technology exceeding IMO emission requirements. These ships will enjoy: • 25% reduction of Initial Registration Fees and; • 20% rebate on Annual Tonnage Tax. (2) Singapore-flagged ships that adopt both energy efficient ship designs and approved SO_X scrubber technology exceeding IMO requirements, will enjoy: • 75 % reduction of Initial Registration Fees and; • 50% rebate on Annual Tonnage Tax.
Green Port Programme	Sea-going vessels that burn clean fuels or use approved abatement technology throughout their entire port stay: • 15% reduction in port dues.	(1) Sea-going vessels that burn clean fuels or use approved abatement technology throughout their entire port stay: • 25% reduction in port dues. (2) Sea-going vessels that burn clean fuels or use approved abatement technology only while at berth: • 15% reduction in port dues.
Green Technology Programme	Grants of up to 50% of qualifying costs with the grant limit being capped at S$2 million per project.	Grants of up to 50% of qualifying costs with the grant limit being increased to S$3 million for projects that can achieve more than 10% reduction in emission levels.

8.4.2 Maritime Singapore Green Pledge

Time	Activity	Proposals	Companies or Organizations
12 April, 2011	The inaugural Maritime Singapore Green Pledge signing ceremony	Promoting and supporting clean and green shipping in Singapore	12 organizations pledged their commitment.
12 January, 2012	The second round of Green Pledge signing ceremony	Be responsible members of the international maritime community by supporting and promoting clean and green shipping in Singapore.	A total of 27 organizations have signed the Green Pledge, and the 15 new signatories include classification societies and shipping lines.
17 October, 2012	The third Green Pledge signing ceremony		Another 13 organizations signed the Maritime Singapore Green Pledge.
3 December, 2013	During the Singapore Registry of Ships Forum on “Responsible Shipping”	Signifying their commitment towards promoting clean and green shipping in Singapore.	20 more maritime companies signed the Maritime Singapore Green Pledge.

8.4.3 Green Ship Programme

The Green Ship Programme is targeted at Singapore-flagged ships. The Maritime and Port Authority of Singapore will provide incentives to ship owners who adopt energy efficient ship designs that reduce fuel consumption and emissions.

Singapore-flagged ships registered on or after 1 July 2011, which go beyond the requirements of the International Maritime Organization’s Energy Efficiency Design Index, will enjoy a 50% reduction on the Initial Registration Fees (IRF) under both the normal registration and the Block Transfer Scheme (BTS) during the registration of the ship. It will also enjoy a 20% rebate on Annual Tonnage Tax payable every year until the ship ceases to exceed the requirements of IMO Energy Efficiency Design Index

Existing ships which utilize energy efficient ship designs that meet the requirements for the Green Ship Programme can also take part in this programme, but will only enjoy the 20% rebate on Annual Tonnage Tax payable every year until the ship ceases to exceed the requirements of International Maritime Organization’s Energy Efficiency Design Index reference lines. For Singapore ships that undergo a change of ownership and the new owner choose to continue registering the ship with Singapore, the new owner pays the registration anew fees. As this fee is not considered as IRF, there is no 50% reduction on the registration anew fees for the new ship owner. However, this ship owner can still enjoy the 20% rebate on Annual Tonnage Tax if the ship qualifies under the Green Ship Programme.

Ships that qualify for the Green Ship Programme will be given a “Green Certificate” issued by MPA. The “Green Certificate” will also be given to the company owning the qualifying ship. A new award category “SRS Green Ship of the Year” will also be introduced in the Singapore International Maritime Awards beginning 2013.

To qualify for the Green Ship Programme, ship owners have to submit a copy of the International Energy Efficiency (IEE) Certificate or pre-verification report as proof that the attained Energy Efficiency Design Index of the ship exceeds the International Maritime Organization’s requirements on Energy Efficiency Design Index for that particular ship type and size at the time when the above financial incentives are to be applied.

If the pre-verification report is not ready at the time of provisional registration, ship owners have to inform the Singapore Registry of Ships in writing at the point of provisional registration of the intention to participate in the Green Ship Programme. The pre-verification report will then need to be submitted within 1 month of provisional registration. For existing ship owners who have made major modifications to make their ships green and would like to enjoy the 20% rebate on Annual Tonnage Tax, please provide the International Energy Efficiency Certificate at least two months before the Annual Tonnage Tax due date. There will be no pro-rated rebate if documentations are not submitted on time. Ship owners can submit a copy of the International Energy Efficiency Certificate from 1st July 2011 onwards.

8.4.4 Green Port Programme

The Green Port Programme (GPP) was announced under the Maritime Singapore Green Initiative to encourage ocean-going vessels calling at the Port of Singapore to reduce the emission of pollutants. Under the Green Port Programme, 15% concession in port dues will be granted to ocean-going vessels that use type-approved abatement/scrubber technology (The abatement/scrubber technology should be type-approved in accordance with IMO guidelines for reducing sulphur oxides (SOx) emission) or clean fuels (For the purpose of the Green Port Programme, clean fuels are defined as fuels with sulphur content of less than 1% m/m) during the entire port stay (of 5 days or less) within the Singapore Port Limits (from the point of entry into Singapore Port Limits till the point of exit). Participation in the Green Port Programme is on a voluntary basis. The Green Port Programme is commenced on 1 Jul 2011 and will be valid for 5 years until 30 Jun 2016.

8.4.5 Green Technology Programme

The Green Technology Programme encourages local maritime companies to develop and adopt green technologies. It provides grants of up to 50% of total qualifying costs (The grant is only applicable for cost incurred after the project has been approved. Applications for retrospective funding will not be considered) to co-fund the development and adoption of green technological solutions. Grants are capped at $2 million per project (The grant is limited to 2 successful applications per company per year, where the 2 technological solutions/systems developed and/or adopted shall be different from each other and from previous application(s). Exceptions may be considered if the technology is similar, but the area of application is different).

The Green Technology Programme is open to Singapore-registered companies engaging in maritime related businesses like terminal operations, ship owning and/or operations and harbour craft operations. Where projects involve ships or harbour craft, the ships or harbour craft must be Singapore-registered and must remain Singapore-registered for a specified period upon completion of the project. Projects should also have verifiable emissions (SO_X, NO_X etc.) reduction results that comply with industry performance guidelines, should be type-approved, have system integration design and retrofitting or installation done in Singapore and have not been commonly deployed in the maritime industry.

8.5 Policy tools and best practices of Hong Kong

8.5.1 reduction of marine emissions in Hong Kong by the International Council on Clean Transportation and Hong Kong Environmental Protection Department (2012)

Measures on marine emissions

(1) Compliance with Annex VI of IMO requirements	(2) Smoke Emission Control	(3) Vessel Speed Reduction	(4) Government Fleet Using Euro-V Diesel: used Euro-V diesel (10ppm S) since 2008.
• Marine fuel sulphur content capped at 3.5% since 2012. • New engines must meet Tier II NO_X emission standard from Jan. 2011. • Other control: banned onboard incineration and use of ozone-depleting substances.	• Excess smoke causing nuisance is offence. • Use Ringelmann chart to assess smoke concentration and take actions against non-complaints.	• Speed control (8-15 knot) in force within and around harbor areas. • When ships slow down: both energy. consumption and Emissions reduce.	

8.5.2 Fair Winds Charter

The Fair Winds Charter is an industry-led voluntary at-berth fuel switching initiative which was initiated during January 2011 to December. 2012 at the beginning and extended until 31 December 2013.17 operators joined the Charter and committed to using 0.5% sulphur diesel when berthing.3,616 vessel calls switched fuel in 2011, accounting for 11% of total vessel calls. This reduced 890 tones SO_2.

The New Initiatives in Policy Address 2011-12:

Benefits: Greatly improve air quality, especially around coastal areas.	
Regional measures in (Pearl River Delta) PRD	Short term goal: Fuel Switch at Berth Long term goal: Emission Control Area (ECA)
Local measures	Improve quality of vessel fuels sold

(1) Regional Cooperation

Regional cooperation is essential to ensure level playing field and maximize environmental benefit. H.K had discussed with Guangdong, Shenzhen and Macao about collaboration on mandating fuel switch at berth in PRD waters and designation of Emission Control Area in the longer term.

(2) Fuel Switch at Berth

Incentive scheme
Sea-going vessel switching to max 0.5% S fuel when berthing will enjoy 50% port facilities and light dues reduction. All auxiliary engines, generators and boilers must switch to low sulphur fuel with sulphur content <= 0.5%.
Effective Date
3-year scheme, launched on 26 September 2012.
The application procedures for the Incentive Scheme
Step 1: One-off registration with EPD for every vessel.
Step 2: Shipping agent / Shipmaster must submit Application-cum-Declaration form to the Marine Department (MD) no later than 4 hours after vessel has switched fuel while berthing.
Step 3: Shipping agent / Shipmaster must submit Fuel Switching Declaration Form, certified true copy of Bunker Delivery Note and certified true copy of Engine Room Log Book to MD within 3 days after leaving HK waters.
Step 4: MD will waive half of the port facilities and light dues payable for eligible vessels upon EPD's advice after initial checking of the required documents.
Participation
As of 30 Nov: 555 vessels of 17 operators registered; A total of 545 vessel calls applied for the Incentive Scheme, we have approved 512 cases, rejected 2and 28 being processed.
Emission Benefits
Using 2010 as the base year, requiring Sea-going Vessels to use fuel with sulphur cap of 0.1% while berthing will reduce territory wide SO2 by 14%, respirable suspend particulates (RSP) by 6%and NO_X by 0.2 %.

(3) Others

Emission Control Area(ECA)
Sea-going vessels must use low-S fuel when operating in PRD waters (ECA S-limit: now 1%, 0.1% from 2015) should an ECA be set up. A long-term goal: to allow time for in-depth studies and other preparations for seeking IMO's approval via Central Government.
On shore power supply
• Explore use of onshore power supply at new KaiTak Cruise Terminal. • Reduce emissions > 90%.

Local Vessels			
1) Local Fuel Quality Upgrade	2) New Initiative	3) Progress	4) Emission Benefits
• HK marine diesel sulphur content is 0.5% (5000ppm). • US, Canada, EU, Australia,	• Cap the sulphur content of local marine diesel at 0.05% (500 ppm). • Benefit: reduce SO_2 by 90%, RSP	• Conducting engine tests for two typical old engines to confirm the technical feasibility of using low sulphur diesel.	• Reduce territory emission of SO_2 by 3.5% and RSP by1.6%.

NZ: 10-15 ppm.	by 30%.	• Next step: Mandate supply of 0.05% S diesel subject to test findings.	
Port Machinery			
1) Control measures		2) Emission Control of non-road mobile machinery	
• Clean Fuels for Port Machinery. • Most quay cranes electric-driven. • Diesel rubber-tyred gantry cranes being converted to electric or hybrid ones. • Euro IV diesel (50ppm S) for mobile machinery.		• Apply emission standards to newly supplied non-road vehicles and machinery, including cargo handling machinery in ports. • Next Step: Introduce legislation in 2013.	

8.6 Summary and Comparisons on Key Points of the Policy tools and Best Practices

	North America		**Asia**	
	USA	**Canada**	**Singapore**	**Hong Kong**
Programmes	San Pedro Bay Port Clean Air Action Plan	Air Action Programme	Maritime Singapore Green Initiative	Fair Winds Charter
Mandatory policy	NA-ECA	NA-ECA, Annex VI of MARPOL, Port Emission Inventory	IMO emission requirements	Annex VI of MARPOL, Tier II NO_X emission standard etc.
Incentive mechanisms	Environmental Shipping Index.	--	Reduction of fees and rebate on taxes	Dues reduction for vessels switching to use low-S fuel.
Best practices	1) For ocean-going vessels and harbor crafts: vessel speed reduction (operational); shore power (technology); fuel switching, hybrid assist tugs (Fuel). 2) For heavy duty trucks, and other off-roads: clean truck program, electric drayage trucks, locomotive upgrade.	1) Emphasizes on regulations, innovation, collaboration and communication. 2) Focuses on development of a data baseline, reducing emissions and tracking progress towards to goal of continuous improvement in terms of reducing emissions form marine vessels, terminals and trucking. 3) Conducting port emissions inventories.	1) Provide incentives to ship owners who adopt energy efficient ship designs that reduce fuel consumption and emissions. 2) Grant vessels that use type-approved abatement/scrubber technology or clean fuels. 3) Encourages local maritime companies to develop and adopt green technologies.	1) Emphasizes on regional cooperation. 2) Set goals for ECA. 3) Fuel Switch at Berth. 4) Measures for local vessels and port machinery.
Key points	1. Compliance with Annex VI of IMO requirements; 2. Emphasis on regulations and collaboration; 3. Exploring to set ECA and Port Emission Inventory; 4. Encouraging and providing incentives for ships to the shore power and promoting the infrastructure			

	construction and international shore power standard.

8.7 Emission Reduction Strategies for Port of Inchon (POI) and Port of Ningbo (PON)

According to the result of monitoring and analyzing the average turn-around time by vessel types, and also the time spent by every stage of ship movement among cruise, hoteling and waiting at anchorage in POI, it is demonstrated that most of emissions occur during the cruise phase and maneuvering, it is clearly indicated that fuel consumption and their consequent harmful gas emissions occur during the high speed period; and therefore, implies that enforcing vessels to slow flowing stream in certain areas will reduce considerable portions of the emissions, as it is the case of the Port of LA/Long Beach.

The emission estimation results of SO_2 and NO_X by vessel types and movement suggest that the POI should consider introducing a speed-reduction zone in its future potential ECA to reduce the emissions during the cruise phase, which has been implemented in some economies e.g. Ports of LA and Long Beach in the USA.

The common phenomenon over the SO_X, NO_X and PM pollutants in POI is five groups of vessels, namely, international ferries, full container vessels, general cargo vessels, car carriers and chemical tankers, comprising 70-76% of their respective total emissions. This suggests that future reduction measures should be focused on these groups of vessels.

Like POI, the monitoring of harmful gas emissions by ship types and movement in PON shows that container ships account for most of emissions; in addition, departure from the dock and cargo handling phases incur major contributions of the emissions. Moreover, the results also indicate that anchoring and maneuvering also cause significant emissions. Therefore, the speed reduction and consideration of setting up future ECAs will provide good options for PON to reduce SO_X and NO_X emissions from ships calling at it.

The monitoring and estimation results also indicate that authorities of both ports should use alternative energy or improve energy efficiency equipment in the port machinery and vehicles to reduce congestion of trucks in the port, and make efforts to improve port management as well.

Chapter 9 Conclusions

Shipping is one of the major sources of air pollution by emitting harmful SO_X and NO_X gases. According to the statistics by IUPPA, ships produce about half as much SO_2 as land-based sources and about a third as much NO_X, and it is estimated that under a business-as-usual scenario, SO_2 and NO_X emissions from ships may increase by 40-50% between 2000 and 2020 globally. These harmful gases, once emitted, would travel across borders and affect land air quality; furthermore, the emission by ships during port stays can be a contributor to the local air quality. (MES, 2005b) The deposition of harmful gases causes acidification, eutrophication and other problems that are disastrous to the environment and human health.

Maritime transportation has been playing a vital role to the rising of intra-APEC trade and that between the APEC and other regions in the world. In recognizing the outstanding importance of efficient and sustainable maritime transportation to the goal of free and open trade in the Asia-Pacific region, APEC leaders and the community as a whole are determined to promote the green development of shipping. Therefore, the control and reduction of emissions from ships has become one of the priorities of the APEC community.

There are various measures that can be adopted by the APEC community to deal with air pollution from ships, these measures as discussed in previous Chapters could be technical, operational and market-based. A holistic and integrated approach will be needed in order to address the air pollution from ships in an effective and efficient manner. Furthermore, the reduction of air pollution from ships will need to be dealt with from the perspective of the entire APEC transport sector and with the participation of all stakeholders, the port industry in particular.

It is important that member economies should have clear vision and commitment to address the air pollution from ships. The appropriate law and regulations need to be established at the national level to prevent and reduce air pollution from ships. The internal reporting and monitoring mechanism should also be put into place to ensure the enforcement of these laws and regulations.

As far as the international regulatory regime is concerned, MARPOL Annex VI provides comprehensive standards to control and reduce SO_X and NO_X emissions from ships. For the APEC community, 13 member economies are already the Parties to Annex VI. Those member economies that are Parties to Annex VI are obliged to implement applicable mandatory requirements to ships under their jurisdictions concerning the SO_X and NO_X emission limits for ships. To that end, member economies will also have to introduce and apply effective emission abatement technologies to their ships to control and reduce emissions, taking into account the safety and efficiency of shipping at the same time.

According to the best practices by the world leading shipping company the Maersk Lines (DNV, 2014), various measures could be taken by shipping companies to reduce emissions from ships. These measures could include the optimization of main and auxiliary engine by applying new techniques; the reduction of lubricant oil and the retrofit of bow and propeller of ships; shipping companies could also optimize voyage by slowing steaming and keeping constant speed, and apply weather routing tools during navigation; furthermore, shipping companies could exercise bunker management to control bunkering inventory, and use alternative clean energy such as liquefied natural gases. It is also important for ships to use optimum hoteling, lights and cargo operations. By taking these technical and operational measures, the fuel efficiency of the Maersk Lines has been continuously improved to meet with its emission reduction objectives. Member economies could encourage their ships to take voluntary reduction measures to improve ships' emission reduction performance.

The cooperation among member economies is also important to reduce the SO_X and NO_X emissions and protect the fragile marine environment and ecosystem in the APEC region, this would include, among others, the information sharing, the capacity building program and the establishment of Emission Control Areas. As far as the latter is concerned, the effect on the shipping industry and the support of relevant technology should be thoroughly considered. There is currently the North America in APEC that is designated as ECA under MARPOL Annex VI.

It is submitted that most of the emissions from ships affecting the APEC region occur within the Exclusive Economic Zones (EEZ) and territorial waters of member economies, therefore, the emphasis of combat measures are to be placed on the port side as far as the practical and policy reasons are concerned. To this end, member economies are encouraged to enforce relevant standards and adopt best practice at national levels to waters under their respective jurisdictions.

The effective way to reduce ship's SO_X emissions is to control the sulphur content of marine bunker fuel. This will involve restricting the sulphur content of bunker fuels being sold to ships in member economies' ports or limiting the sulphur content of bunker fuels being used by ships calling at member economies' port or navigating in adjacent waters, or perhaps doing the both. The regulation of bunker fuels being sold would be achieved by merely imposing obligations on oil refinery sector, so as to prohibit the sale of bunker fuels with the sulphur content above the limits as set out in MARPOL Annex VI. The regulation of bunker fuels being used by calling ships is feasible, but also will raise the issue if member economies as port States are entitled to require foreign ships visiting their ports to comply with requirements beyond international standards. Therefore, the control measures in this respect would need careful implementation and complement with incentives.

It should be noted that the use of low sulphur marine fuel still depends on the availability of the MARPOL Annex VI compliant fuel, particularly the post-2020 marine fuel with 0.5% sulphur content. In this regard, the refinery industry is of vital importance in supplying sufficient available fuel to the maritime sector, and the refinery capacity is also critical in evaluating the fuel availability for ships to meet both the current and future SO_X emission limits as required in MARPOL Annex VI. It is unclear at present if the global demand for low sulphur marine bunker fuel could be met in a timely manner taking into account the huge investment and considerable time needed for the refinery industry to expand and upgrade its capacity to produce compliant fuels. Therefore, a comprehensive assessment of the world refinery capacity is important to provide an overall perspective of demand and supply of low sulphur marine fuel for the maritime sector. IMO is now preparing the review of fuel availability to meet the post-2020 SO_X emission standard, it is expected that the outcomes of the review would provide certainties to the shipping industry to comply with the SO_X emission standard after 2020.

The reduction of NO_X emission could also be achieved by limiting the emissions from ships calling at the ports of member economies; however, as the NO_X emissions standards involve the engine design and improvement technologies which are decided entirely by the flag State of ships, therefore, port-based standards, if imposed, would also need to be complemented by incentives.

The experience and practices by some member economies and European States have shown that the reduction of SO_X and NO_X emissions from ships requires the combination of regulatory tools with market-based instruments. Economic incentives applied to reduce ships' emissions will not raise enforcement issues but encourage through pricing mechanisms ship owners and operators of ships calling at APEC ports to voluntarily use lower sulphur fuels and to invest in techniques needed to ensure a distinct reduction of NO_X emissions.

Economic incentives applied to ships' emission reduction are entirely port-based. Port States are free to set up their own incentive schemes, including environmental differentiated taxes and charges. However, it should also be noted that the establishment of economic schemes will be determined by various factors, such as the basis on which the fee is set (for instance, gross tonnage, emission volume and voyage distance etc.); the degree and fee level of differentiation; the frequency with which a ship is expected to confront the differentiated fees; the geographical area of application as well as ship's specific characteristic (BMT, 2000).

In connection with the application of economic incentives, it should also be noted that such schemes should not infringe the competition policy in the APEC region, therefore, a harmonization would be needed to ensure the implementation of the economic incentives in a fair and transparent manner, and APEC ports are at a level playing field without being put into a disadvantageous position.

The application of shore power provides an alternative option to reduce ship's emissions. This will not only save the energy cost of ship owners, but also reduce emissions and engine noise of ships in ports.

There is a significant reduction potential for emission reduction in the ports for using shore power, and many ports are now using or considering using this option. However, there are also limitations of using shore power. The provision of shore power will require port authority to construct necessary infrastructure, and ships will also need to install connection equipment, therefore, the connection standards that are globally acceptable will be needed; furthermore, the production of shore power will also have the risk of shifting the air pollution problems, particularly in the situation when the shore power is produced by fossil based power stations in ports. Therefore, clean energy such as solar or wind power is preferable to produce shore power as these sources are emission free and will not cause other air pollutions.

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