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The Prevention and Control of Shipping and Port Air Emissions in China

China is home to seven of the world's ten busiest container ports. About 26 percent of the world's containers pass through the top ten Chinese ports every year (see Table 1). However, every ship and truck brings pollution along with its cargo. With ships allowed to burn fuel with much higher sulfur levels than permitted in on-road diesel, one container ship cruising along the coast of China emits as much diesel pollution as 500,000 new Chinese trucks in a single day.

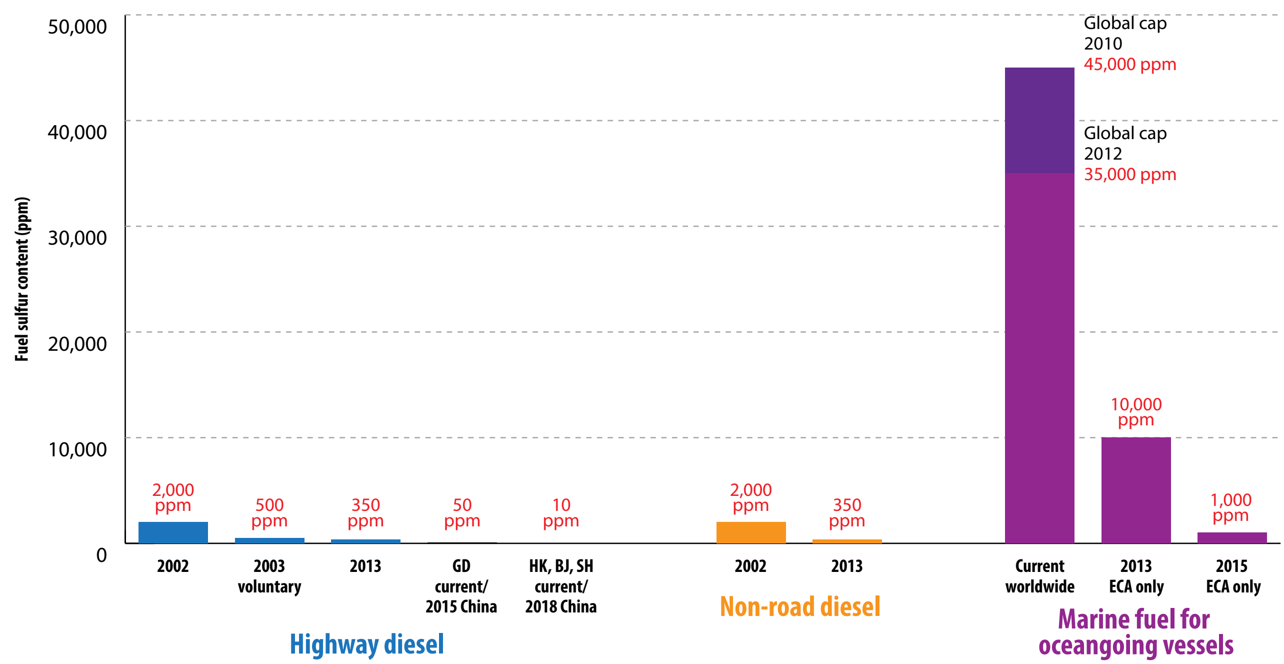
Table 1: Top 20 container terminals and their throughput for 2013[1]

Rank	Port name	Country	Volume, million TEU	Share of world container volume
1	**Shanghai**	**China**	**33.6**	**5%**
2	Singapore	Singapore	32.6	5%
3	**Shenzhen**	**China**	**23.3**	**4%**
4	**Hong Kong**	**China**	**22.3**	**3%**
5	Busan	South Korea	17.7	3%
6	**Ningbo-Zhoushan**	**China**	**17.4**	**3%**
7	**Qingdao**	**China**	**15.5**	**2%**
8	**Guangzhou**	**China**	**15.3**	**2%**
9	Dubai	United Arab Emirates	13.5	2%
10	**Tianjin**	**China**	**13.0**	**2%**
11	Rotterdam	Netherlands	11.6	2%
12	Port Klang	Malaysia	10.2	2%
13	**Dalian**	**China**	**10.0**	**2%**
14	**Kaohsiung, Taiwan**	**China**	**9.9**	**2%**
15	Hamburg	Germany	9.2	1%
16	Antwerp	Belgium	8.6	1%
17	**Xiamen**	**China**	**8.0**	**1%**
18	Los Angeles	United States	7.9	1%
19	Tanjung Pelepas	Malaysia	7.5	1%
20	Long Beach	United States	6.7	1%
Total for Chinese ports in top 20			**168.3**	**26%**
World's top 20			**293.8**	**46%**
World total			**641.0**	**100%**

HEALTH AND ENVIRONMENTAL IMPACTS OF SHIPPING AND PORT EMISSIONS

Most ships at Chinese ports run on bunker fuel, also known as residual fuel. Almost all port vehicles and equipment are powered by diesel fuel. The exhaust from all of these engines contains high levels of diesel particulate matter (PM), oxides of nitrogen (NO_x), and oxides of sulfur (SOx). NO_x emissions from diesel engines also contribute to increasing regional ozone (O_3) and fine PM. These emissions are associated with a wide range of respiratory and cardiovascular illnesses, and diesel PM is known to cause cancer.[2,3] PM from diesel or bunker fuel combustion contains black carbon, a short-lived pollutant that is accelerating glacial and polar ice melting, exacerbating climate change. NO_x and SOx emissions from diesel engines also cause acidification, eutrophication, and nutrient enrichment of ecosystems, contributing to ocean acidification.[4] The very high level of sulfur in marine bunker

Figure 1: Fuel sulfur standards for diesel trucks (highway diesel) and non-road diesel engines adopted in China and IMO fuel standards for oceangoing vessels[5]



Dates indicate the year in which each standard became effective. SH denotes Shanghai, GD denotes Guangdong, HK denotes Hong Kong, BJ denotes Beijing, and ECA denotes Emission Control Area designated by the International Maritime Organization (IMO); lower sulfur limits have been enforced in key regions, including Beijing, Shanghai, Guangdong, and Hong Kong.

ppm: parts per million.

fuel—100 to 3,500 times higher than permitted in on-road diesel fuel—and the high sulfur content of dirty diesel used in developing regions, like most part of China, can impair or destroy advanced emission control systems on trucks and vessels, hence preventing the use of these control systems on oceangoing vessels (OGVs) and trucks in most part of China. Figure 1 gives comparisons of the sulfur content of on-road diesel and non-road diesel sold in China and marine fuel for OGVs.

SHIPPING AND PORT ACTIVITIES POLLUTE THE AIR IN CHINA'S PORT CITIES

China is paying a high price for pollution from shipping. In 2010 the country saw an estimated 1.2 million premature deaths caused by ambient air pollution. According to studies conducted in Hong Kong and Shenzhen, shipping is a significant source of these air pollution and health problems, particularly in port cities.[6] Figure 2 shows the contribution of the shipping sector's emissions to overall emissions in Hong Kong.[7] Since Chinese port cities are among the most densely

Figure 2: Contribution of marine emissions to the total emission profile of Hong Kong, 2012 data[8]

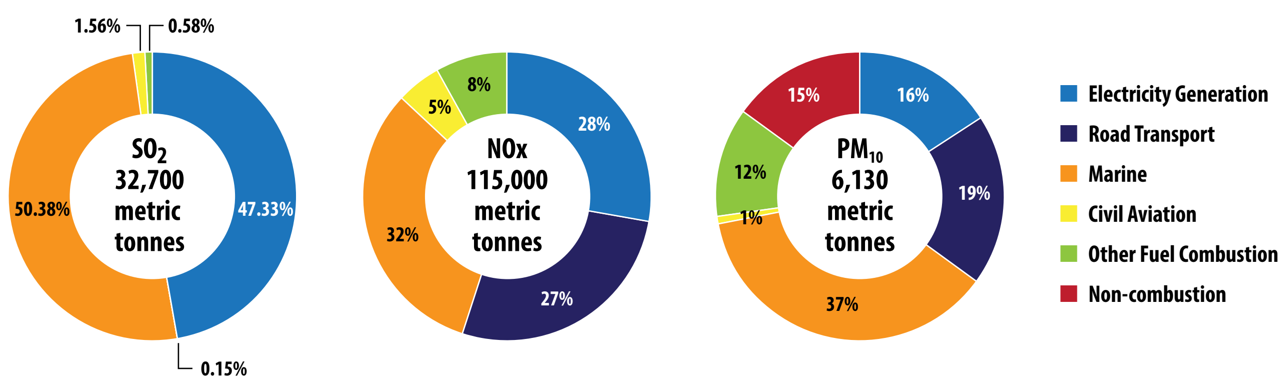
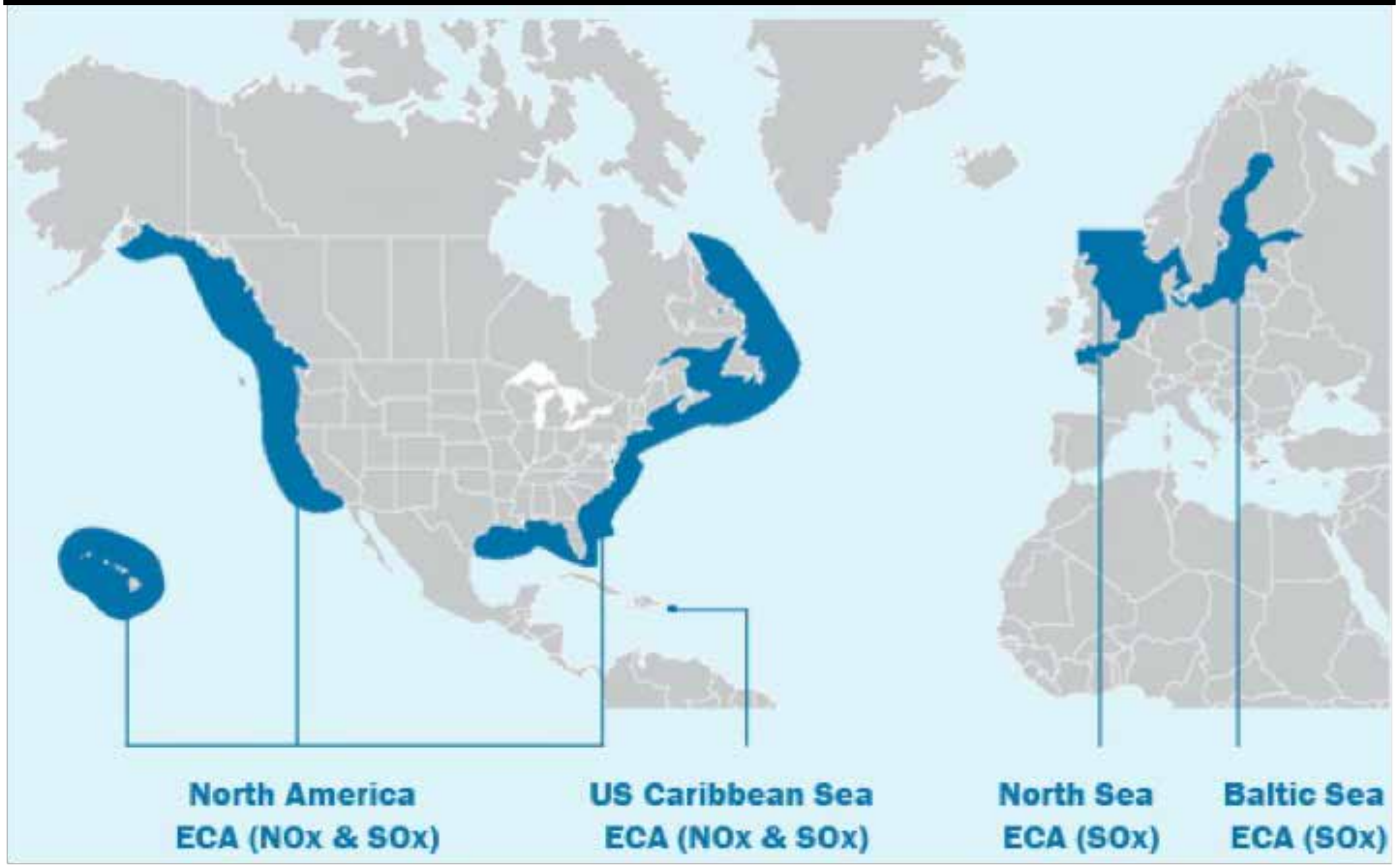


Figure 3: Coverage of the four ECAs



Note: Secondary PM emissions are indirectly regulated through the SOx limits enforced in the SOx ECAs.

populated with the busiest ports in the world, air pollution from ships and port activities likely contributes to much higher public health risks than are found in other port regions.

ALLEVIATING POLLUTION FROM SHIPPING AND PORT ACTIVITIES

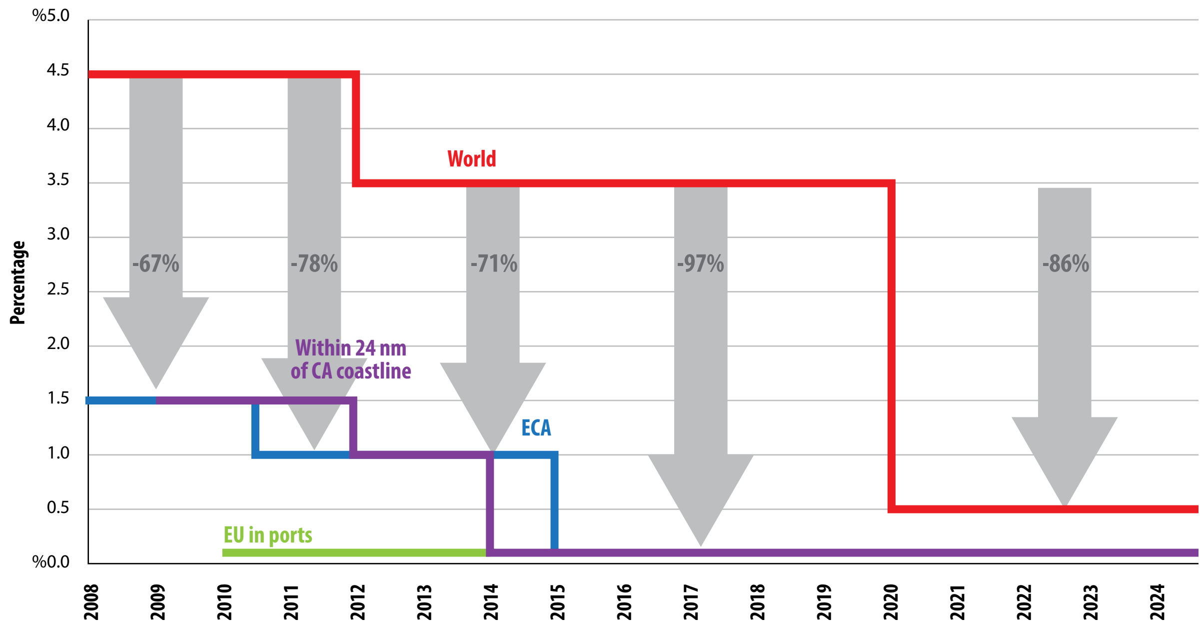
Recognizing the health and environmental impacts of shipping, governments in North America, Europe, and some regions of Asia (including Singapore, Hong Kong, and Shenzhen) have taken steps to regulate shipping and port emissions and/or launched programs to encourage the use of low-sulfur fuel and clean technologies. For ocean shipping, the United Nations International Maritime Organization (IMO) has adopted SOx, PM, and NO_x standards targeting oceangoing ships.[9] The IMO has also designated four regions as Emission Control Areas (ECAs) (see Figure 3).

The world's average marine fuel sulfur level is 26,000 parts per million (ppm)—2.6 percent—and the global sulfur cap set by the IMO is 35,000 ppm (3.5 percent). Stricter SOx (and indirectly PM) emissions limits are imposed in the four ECAs shown in Figure 3; ships operating within these four ECAs must use fuel with 10,000 ppm (1 percent) or less sulfur content. The fuel sulfur cap in the ECAs will be lowered to 1,000 ppm (0.1 percent) beginning on January 1, 2015.[10]

The North American ECA (within 200 nautical miles of the North American coast) and the U.S. Caribbean ECA are also ECAs for NO_x. Starting in 2016, new OGVs traveling within these ECAs will be required to reduce NO_x emissions by 75 percent.[11]

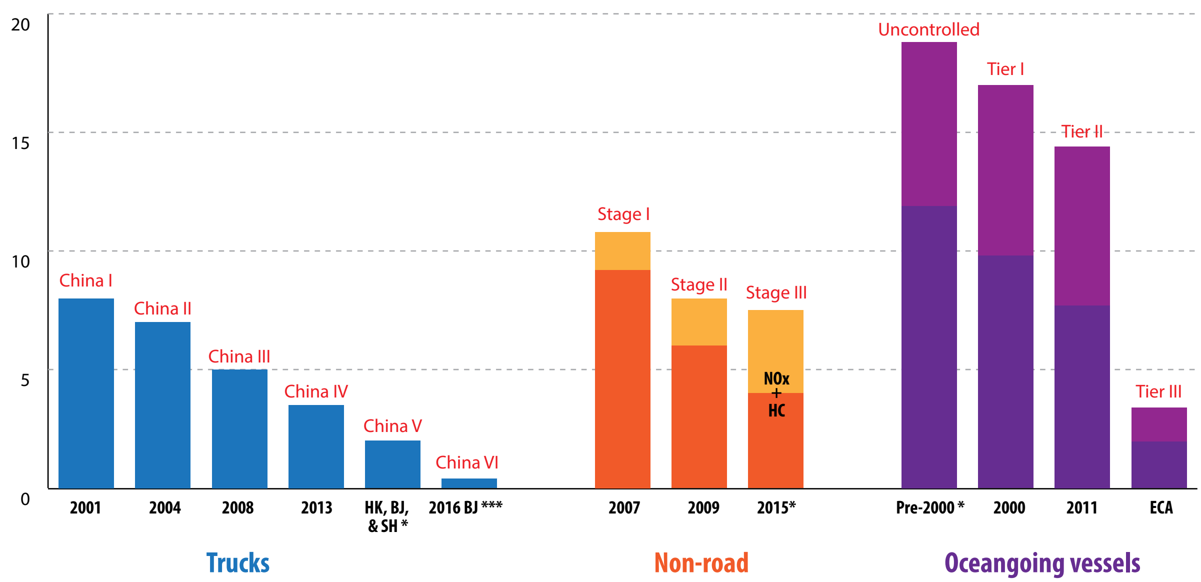
Vessels plying inland waterways in the European Union (EU) and U.S.-registered non-oceangoing vessels operating within the United States are required to meet even stricter fuel sulfur and NO_x emission standards than are applied to ships in ECAs.[12] See Figure 4 for various sulfur limits for marine fuels in the United States, EU, and other regions, and Figure 5 for comparisons of NOx emission standards for China's trucks and non-road engines, and marine engines.

Figure 4: IMO fuel sulfur standards for vessel fuel, and fuel sulfur limits at EU ports and in California waters for the years 2008 to 2025[13]



The above line for the California fuel sulfur standard shows the sulfur standards for marine gas oil (MGO, or DMA under ISO designation); there is a stricter standard for marine diesel oil (MDO, or DMB under ISO designation) requiring a sulfur level not exceeding 0.5 percent beginning July 1, 2009, and 0.1 percent from January 1, 2014 onward. The Baltic Sea and the North Sea ECAs went into effect in 2006 and 2007 respectively. The North American ECA was implemented on August 1, 2012, the same date that the California 1 percent fuel sulfur limit came into effect.

Figure 5: NO_x emission standards for on-road and non-road diesel engines adopted in China, and marine engine emissions standard adopted by the IMO[14]



Dates indicate the year each standard became effective. The faded colors indicate the range of NO_x standards, which vary by engine power or speed. The NO_x standards for China non-road engines are based on power output, and IMO NO_x standards for OGVs vary by maximum engine speed. SH represents Shanghai, HK represents Hong Kong, and BJ represents Beijing.

* A national China V standard for diesel trucks (depicted by the yellow bar labeled "HK, BJ & SH") has been adopted, but enforcement across the nation has been delayed, and an implementation timeline has not been announced. The standard is in effect in Hong Kong, Beijing, and Shanghai only. The latest standard for non-road diesel engines, which sets a limit for the sum of NO_x and hydrocarbon (HC) emissions, will go into effect October 1, 2015.

** Uncontrolled OGV emissions are calculated on the basis of published emissions factors of container cargo ships.[15]

*** The China VI standard represents Beijing's commitment to enforce emission standards more stringent than China V by 2016.

COST-EFFECTIVE ECA REGULATIONS CAN PROMOTE CLEAN TECHNOLOGIES

The ECA regulations are expected to be highly cost-effective: The low-sulfur marine fuel standards enforced in the North Sea and Baltic Sea ECAs are projected to result in public health and environmental benefits four times the cost of compliance. For the North American ECA, the benefits from implementing the NO_x, PM and SOx standards are expected to be more than ten times greater than compliance costs.

These regulations, along with incentive programs, have also driven the development and deployment of alternative fuel and advanced emissions control technologies on ships. While switching to lower-sulfur marine fuel remains the most common approach for meeting the fuel sulfur mandates, some ship operators are testing the feasibility of scrubbers for cleaning up tailpipe SOx emissions.[16] Advanced NO_x emissions control technologies, such as selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) devices, have been deployed on ships because of incentives and the strict NO_x emissions requirement to go into effect in North America.[17] Ships powered by liquefied natural gas (LNG) are gaining traction in the United States, the EU, and China, owing to the lower NO_x, SOx, and PM emissions from LNG vessels and the lower costs compared with low-sulfur marine diesel in the United States and the EU.[18] An increasing number of ports in Europe, the United States, and China are building LNG bunkering facilities.[19] Some ports in the United States and the EU also promote, or even mandate, the use of shore power and vessel speed reduction to further lessen vessel emissions at or near ports.[20]

INITIAL STEPS TO CLEAN UP CHINA'S SHIPS AND PORT OPERATIONS

In China, severe air pollution episodes from recent years have prompted the government to adopt a new set of ambient air quality standards and implement a series of measures for improving air quality. However, only a few port cities and provinces have begun to pay attention to emissions from ships and port activities. Hong Kong is the first to strictly enforce the use of low-sulfur fuel (500 ppm, or 0.05 percent sulfur content) by local vessels, and it will soon be the first in China to mandate that OGVs use lower-sulfur marine fuel while docking.[21,22] Shenzhen has followed Hong Kong, announcing a comprehensive list of measures for cleaning up ships, trucks, and port equipment, including offering subsidies to encourage fuel switching at berth and the use of shore power.[23] Other port cities and regions like Shanghai, Qingdao, and the provinces of Guangdong, Jiangsu, and Shandong have also issued plans to promote shore power, electrification of port equipment, and trucks powered by electricity or natural gas.[24] All in all, measures adopted for the control of air emissions from shipping and ports, as well as related research, are still at an early stage in China, and there are still many gains to be made. Cleaning up ships, trucks, and port equipment, therefore, can contribute significantly to the important air quality improvement efforts undertaken by coastal regions.

While the announcement of clean port/clean shipping plans are encouraging, most of these plans were proposed by a city or provincial government without detailed, port-specific analysis due to a lack of data. The plans lay out only high-level goals, and implementation details—such as penalties or incentives to ensure attainment of these goals—need to be worked out by the city or provincial agencies in charge and agreed upon by various stakeholders, including the industry. Without solid analysis to support the proposed goals, these plans are susceptible to opposition from the port and shipping industry. Furthermore, unless port cities cooperate on regional emission control measures, the fear that ships will shift to less regulated ports could prevent port cities from adopting stricter measures, such as mandating the use of low-sulfur fuel. If regulation were to drive ships to other ports, such "leakage" would merely shift pollution from one port to another and seriously undermine the overall effectiveness of clean port and shipping measures.

PORT-SPECIFIC STRATEGIES AND ECA ARE CRITICAL

To address these challenges and knowledge gaps, more research is needed to establish emission inventories and evaluate the costs and benefits of various pollution control measures specific to individual ports or regions. As the costs and benefits of measures like shore power or the use of liquefied natural gas could vary substantially depending on port-specific conditions, such analysis could help ports prioritize and best direct resources to strategies that maximize emissions reductions. This analysis could then be used to formulate clean port plans that guide efforts to reduce air pollution from shipping and port activities. Research to assess the impacts of regulation on port competitiveness and how to address those impacts would also help garner broader support for port and shipping emissions control programs. Ultimately, a regional or even national approach to reducing marine and port emissions, such as the establishment of an Emission Control Area, would be the best way to prevent ships from evading their responsibility by transferring to ports with lax environmental requirements, and would ensure that any program adopted in China will achieve the expected emissions control and health outcomes.

Endnotes

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8 Hong Kong Environmental Protection Department (HKEPD), *2012 Hong Kong Emission Inventory Report*, Hong Kong SAR Government, March 2014, www.epd.gov.hk/epd/english/environmentinhk/air/data/files/2012HKEIReport_eng.pdf.

9 IMO enacts environmental regulations through the International Convention for the Prevention of Marine Pollution from Ships (MARPOL). Annex VI of the Convention specifically deals with the prevention of air pollution from vessels. The countries and regions mentioned here have all ratified MARPOL Annex VI and are taking regulatory steps under the framework of Annex VI. See more details in the full report: Freda Fung et al., *White Paper on the Prevention and Control of Shipping and Port Air Emissions in China*, Natural Resources Defense Council, October 2014.

10 According to MARPOL Annex VI, sulfur levels in the North American, Caribbean, Baltic, and North Sea ECAs will be capped at 1,000 ppm (0.1 percent) in 2015. SOx emissions outside the ECA are controlled mainly through a global fuel sulfur standard of 35,000 ppm (3.5 percent) for fuel oil. See IMO, "Sulfur oxides (SOx)," endnote 5.

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12 Non-oceangoing vessels in the United States are powered predominantly by Category 1 and 2 engines (engine cylinder displacement smaller than 30 dm^3). These vessels include tugboats, push boats, supply vessels, fishing vessels, and commercial vessels that operate in or near ports.

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14 "China: Non-road: Emissions," TransportPolicy.net, http://transportpolicy.net/index.php?title=China:_Nonroad:_Emissions (accessed May 1, 2014). IMO, "Nitrogen Oxides (NOx)," endnote 11.

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