NRDC

NATURAL RESOURCES DEFENSE COUNCIL

REPORT

MOBILE SOURCE EMISSION ASSESSMENT FROM PORT PLANNING TO OPERATION: INTERNATIONAL BEST PRACTICES

JUNE 2020

NATURAL RESOURCES DEFENSE COUNCIL

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EXECUTIVE SUMMARY

China is home to seven of the world's top ten ports and processes 30 percent of the world's shipping containers every year. However, with every ship and truck entering these ports come not only cargo but also air pollution. Most ships at Chinese ports are fueled by distillate or residual fuel, both with more sulfur than road fuels. Most of the port vehicles, cargo handling equipment, and rail locomotives are powered by diesel fuel. The exhaust from all of these engines contains high levels of diesel particulate matter (PM), nitrogen oxides (NO_x), and sulfur oxides (SO_x). NO_x emissions from diesel engines also contribute to increasing regional ozone (O_3) and fine PM, threatening human health and the environment. Port and shipping emissions have become one of major sources of air pollution for densely populated coastal cities in China, such as Hong Kong and Shanghai.

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With China's policies to strengthen transportation and to build world-class ports, the port and shipping industry will be enhanced and experiencing new development. Construction of new ports and expansion of old ports could induce more water and road transportation in port cities. As a result, the total emissions from ships, vehicles, and cargo handling equipment can increase greatly if no appropriate mitigation measures are applied.

Controlling mobile source pollution has become one of the top priorities of combating air pollution in China. China's *Three-year* Action Plan for Winning the *Blue Sky War* emphasized the urgent need to set up an integrated strategy for effective control over trucks and off-road mobile sources, including vessel and port equipment.

Environmental Impact Assessment (EIA) aims to mainstream environmental issues into decision-making at an early stage. Thus, EIA can be a useful tool for assessing the air pollution caused by port development and expansion and integrating prevention and mitigation measures into the decision-making on port development and expansion.

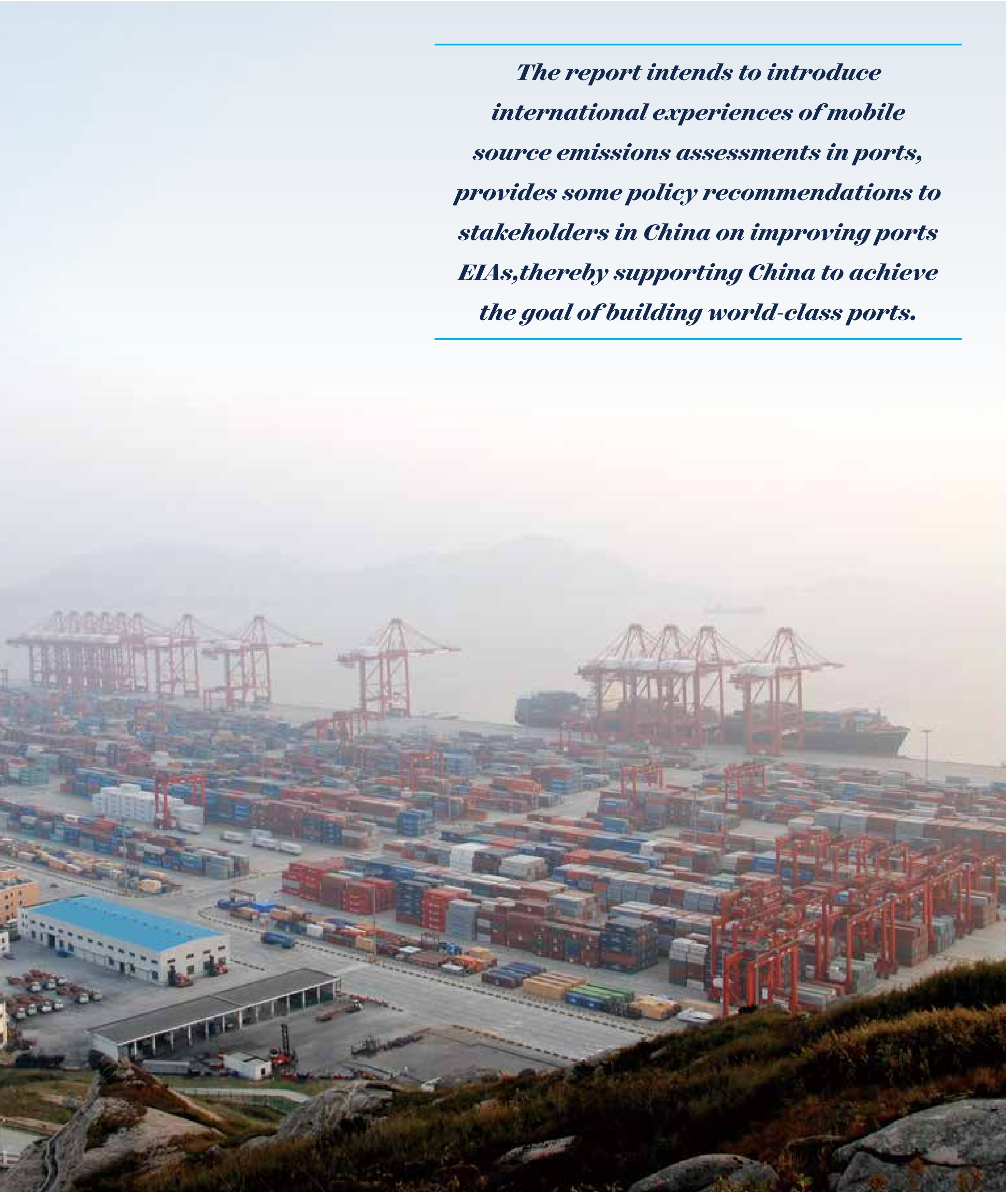
China's port planning EIA was officially launched in early 2000s. Great progress has been achieved with nearly 20 years of development, especially with the release of *Technical Key Points of Environmental Impact Assessment for the Port Master Planning* in 2012 and the publishing of Technical Specification on overall port planning EIA in 2018. However, port-related mobile sources assessment was limited or even a weak piece in China's port planning EIA practice.

In the United States and European Union (EU) countries, port EIAs require the assessment of the environmental and social impacts of port development on a wide range of issues, including air quality, and mobile sources assessment is an essential part of it. Pending the proposed development, a systematic approach is taken to estimate air pollutant emissions from port-related emissions sources, including e.g. vessels, cargo handling equipment, heavy-duty vehicles, harbor crafts, and rail locomotives.

The report intends to introduce international experiences of mobile source emissions assessments in ports, especially the cases from the Port of Rotterdam in the Netherlands and the Port of Los Angeles and the Port of Long Beach in the U.S. Drawing on lessons learned from the case studies, this report provides some policy recommendations to stakeholders in China on improving ports EIAs:

- Port planning EIA can be a useful tool for facilitating the prevention and reduction of shipping and port emissions.
- Implement atmospheric environment monitoring and setting up environmental monitoring stations in port areas, to capture long-term, continuous, and full-factor atmospheric environmental monitoring data.
- Construct a comprehensive port emission inventory by incorporating all kinds of mobile source and stationary source, and regularly updating the list of emission sources in support of an effective EIA for ports.
- Develop a scientific and effective port air pollution model that considers the interaction of sea and land atmospheres to serve as a powerful tool for EIA analysis and prediction.
- Expand the scope of ports EIA, assessing not only construction stage air pollution but also air pollution from mobile sources (ships, trucks, port equipment, and railway) during future port operations, and most important consider adding GHG indicators to promote the co-control of air pollution and greenhouse gases.
- Take port planning EIA as the first step of the port atmospheric environment management, proposing specific, targeted and operable air pollution control measures, and carrying out port air pollution control actions through the whole process of port construction and operation.
- Clarify the responsibilities of environmental and transportation agencies, port authorities, ship owners, and other relevant enterprises and institutions in port environmental management, establish a coordination mechanism, promote the disclosure of environmental information, and encouraging more social organizations and the general public to participate and to play active roles on social supervision in the management of port EIA and thus to effectively control port air pollution.

The report intends to introduce international experiences of mobile source emissions assessments in ports, provides some policy recommendations to stakeholders in China on improving ports EIAs,thereby supporting China to achieve the goal of building world-class ports.



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INTRODUCTION

Ports are a vital part of the Chinese economy, with seaports and inland river ports serving as gateways for moving freight and passengers across the country and around the world. China is home to seven of the world's top ten ports and processes 30 percent of the world's shipping containers every year. However, with every ship and truck entering these ports come not only cargo but also air pollution. Most ships in Chinese ports are fueled by distillate fuel or residual fuel, both with more sulfur than road fuels. Almost all port-related trucks, cargo handling equipment, and locomotives are powered by diesel fuel. The exhaust from all of these engines contains high levels of diesel particulate matter (PM), nitrogen oxides (NO_x), sulfur oxides (SO_x) and carbon dioxide (CO_2), which adversely affect human health and the environment.[1] Ports and shipping emissions have become one of major sources of air pollution in China, especially for densely populated coastal cities. According to the latest emissions inventory developed for Hong Kong, Shenzhen, and Shanghai,[2] emissions from ships and port activities are a significant portion of the total emissions in the three cities, as presented in Table 1. Port-related diesel-powered vehicles, equipment, and ships also produce significant greenhouse gas (GHG) emissions that contribute to climate change.

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Controlling mobile source pollution has become one of the top priorities of combating air pollution in China. In 2018, China's State Council released a three-year Action Plan for Winning the Blue Sky War (BSDP, 2018-2020), which aimed to strengthen national efforts to combat air pollution.[4] As vehicles, non-road equipment and ships have become some of the biggest sources of air pollution in large cities, the plan identifies the need for effective control over mobile source emissions within the next three years and sets up an integrated intervention strategy, the "Fuel-Road-Vehicle" Scheme.

In September 2019, the Chinese national government issued a policy outline to build China's strength in transportation.[5] The policy requires to build a modern and comprehensive transportation system that is safe, convenient, efficient, green, and economic. Afterwards, the Ministry of Transport (MOT) and nine other government agencies jointly released guidelines to accelerate the building of world-class ports[6]. According to the guidelines, world-class ports should be green, smartly built, and enhance high quality development.

An Environmental Impact Assessment (EIA) aims to mainstream environmental concerns into decision-making at an early stage. Thus, an EIA can be a useful tool for assessing the air pollution caused by future development and expansion of ports and for integrating prevention and mitigation measures into the decision-making stage on port development and expansion. If well designed and implemented, clean-air measures and potential incentive programs proposed in the EIA could also strengthen ports' competitiveness in the context of a slowdown

TABLE 1. SHARE OF LOCAL PORT AND SHIPPING AIR POLLUTION[3]

PORT CITY	SO_2	NO_X	$PM_{2.5}$	YEAR
Hong Kong	52%	37%	41%	2017
Shenzhen	59%	16%	5%	2013
Shanghai	26%	29%	4%	2015

in growth for the shipping industry worldwide. Furthermore, win-win solutions in air quality and ports and shipping growth could be achieved.

In China, Environmental Impact Assessments were first stipulated in 1979 through the Law of Environmental Protection (for trial implementation). Starting September 2003, when the Environmental Impact Assessment Law came into effect, the EIA system began to be implemented systematically.[7] In 2004, China started its port master planning EIA process. In 2011, China MOT published *Specifications for Environmental Impact Assessment of Port Engineering (JTS 105-1-2011),* which particularly instructs project EIA process and environmental management for port development.[8]

Air pollution assessment is one part of the port EIA, as indicated in the Port EIA regulations. Generally, for an EIA, it is required to analyze, forecast and evaluate all possible environmental impacts. Mobile source emissions from ports activities and shipping are one of major sources of air pollution. However, neither the general EIA law and regulations nor professional specifications on port EIA specified the requirement to regulate and assess mobile source emissions. In 2012, the Ministry of Environmental Protection (MEP) and the Ministry of Transport jointly circulated *a Promulgation on Further Strengthening EIA of highway and Waterway Transportation Planning.* In the Appendix I of the Promulgation, the *Technical Key Points of Environmental Impact Assessment for the Port Master Plan* (the TKP), guidance on performing port planning EIA was provided. However, the TKP only requires the assessment of ship exhaust for EIAs of busy inland river ports.[9] Air pollution from mobile sources in other types of ports, e.g. seaports, is neither identified as a major source of pollution nor considered in the air pollution assessment. Thus, in practice, very few of the mobile sources in ports, including vessels, trucks, cargo handling equipment, and locomotives, has been analyzed, forecasted or evaluated in the port EIAs in China. Therefore, while the previously mentioned emission inventory data revealed ship and port activities to be major sources of air pollution in ports, they have been underestimated in EIAs. In recent years, ship emissions have been gradually included in the EIA report, and a few port planning EIA has considered the emissions from trucks and port equipment, but their geographic scope was limited to the port boundary.

In China, Environmental Impact Assessments were first stipulated in 1979 through the Law of Environmental Protection (for trial implementation). Starting September 2003, when the Environmental Impact Assessment Law came into effect, the EIA system began to be implemented systematically.

The air pollution assessment should be integrated into the EIA for port planning and projects, including scoping (identifying all sources of air pollution), air pollution emissions forecasts, assessment of impacts on ambient air quality, formulation of recommendations, mitigation measures for the port plans and projects, and development of follow-up evaluations and monitoring programs.

The United States and some European countries have many years of experience in preventing and controlling pollution from shipping and ports. Port EIAs in the United States and European Union (EU) member countries require the assessment of impacts of port development and expansion on air quality both within and beyond the port. It is worth learning from U.S. and EU practices on air pollution assessment in ports' EIAs, both in terms of regulations and methodology. In the U.S. and the EU, EIA and environmental permitting for ports have been combined to ensure the sustainable development of ports. In addition, the follow-up mechanism, especially with respect to environmental monitoring in ports, is designed for evaluating the effectiveness of mitigation measures and allows prompt adjustments.

This report examines current and future emissions from a variety of mobile sources operating in port areas, introduces international experiences of mobile source emissions assessments in ports, and explores the potential of a range of available strategies to reduce emissions from port-related trucks, locomotives, cargo handling equipment, harbor craft, and ocean-going vessels. It first summarizes the country-specific regulations in port EIAs in China, the United States and the European Union, followed by an introduction to general processes on mobile source assessment and case studies in California, U.S. (the Port of Los Angeles and the Port of Long Beach) and Rotterdam, the Netherlands (the Port of Rotterdam). Drawing on lessons learned from the case studies, this report concludes with some recommendations to stakeholders in China on improving EIAs for ports tailored to China's context. We hope the report could help China to continue to improve port EIA practices such that various clean port measures now being promoted in China, such as on-dock rail, shore power, low-/zero-emission trucks and port equipment, would be integrated in the port planning process and their benefits fully accounted for.

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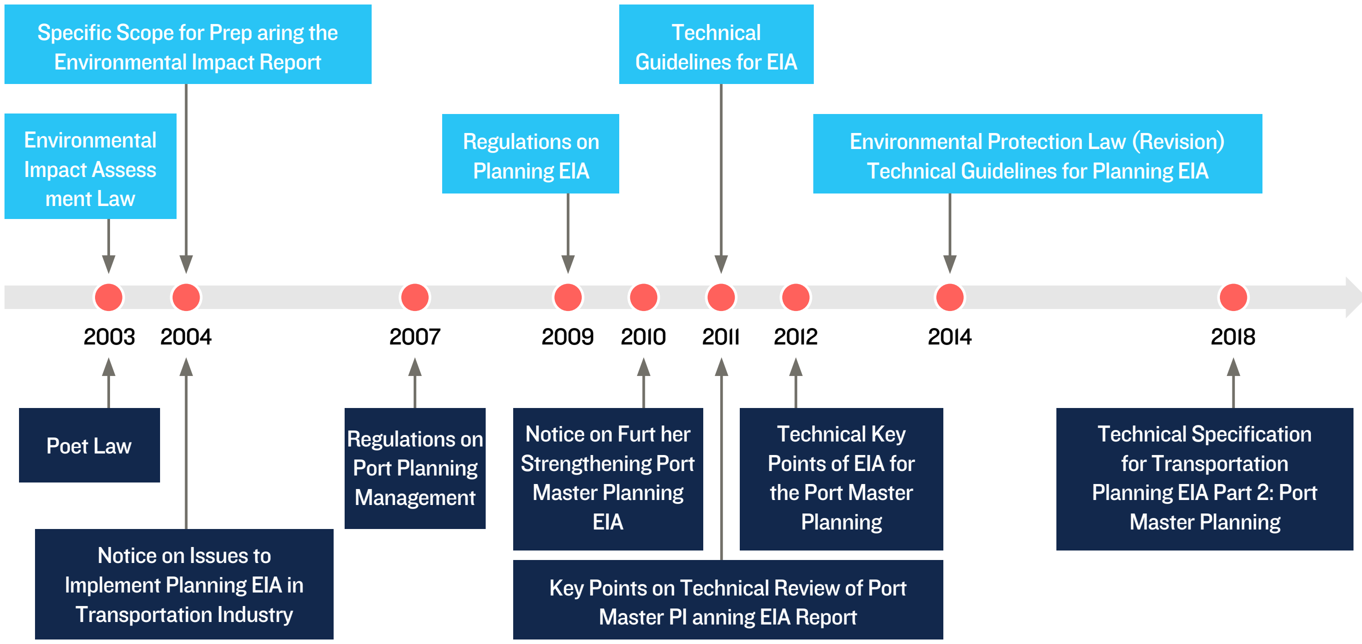
OVERVIEW OF CHINA'S PORT EIA

Environmental Impact Assessment, especially Planning Environmental Impact Assessment, evaluates the possible major environmental impacts during the early stage of project decision-making, and incorporates prevention and mitigation measures into the decision-making of project development. After nearly 20 years of practice, China's port planning EIA has made great progress and played an important role in effectively preventing the adverse impact of port development on the ecology and environment. However, as an important source of port emissions, the emission assessment of mobile sources is still a relatively weak part in the port planning EIA.

FIGURE 1. CHINA'S PORTS EIA POLICIES AND REGULATIONS DEVELOPMENT TIMELINE[10]



2.1 CHINA'S PORT EIA POLICY DEVELOPMENT

EIA was first introduced to China in late 1970s. Enactment of the Environmental Impact Assessment Law (EIA Law) in September 2003 marked a milestone of the systematic and legal development of EIA in China. EIA is not only a technique but also a legal statute for environmental management. Following the implementation of the EIA Law, the environmental protection authority and the transportation authority issued a series of policies and regulations to reiterate the importance of carrying out port EIAs per the EIA Law and gradually to clarify the working procedures on preparing a port EIA. The development process of port planning EIA and the release sequence of corresponding documents are illustrated in Figure 1.

Port planning and project construction EIAs follow different standards and guidelines. This report will focus on analyzing EIA processes at the port-planning phase, i.e., the Planning EIA. The Planning EIA is also referred to as the Strategic Environmental Assessment (SEA) in EU countries. The Planning EIA process should identify, describe, and evaluate all significant effects that the plan implementation might have on the environment. It should examine reasonable alternatives while taking into account the plan's goals and its geographical scope. Indeed, the Planning EIA can be considered a decision-support instrument aimed at providing as detailed a picture as possible of the environmental impacts related to the implementation of a plan, policy or program. The Planning EIA must contain sufficient information to assess the acceptability of the impacts, and, consequently, to propose suitable modifications and mitigations.

At present, China has not made special provisions for ports planning and construction engineering EIAs in the laws and regulations related to ports and environmental assessments. Article 7 (2) of the Port Law requires that *"When preparing for port planning, expert review process shall be organized and environmental impact assessment shall be conducted according to the law."*[11] Article 19 of the Port Planning Management Regulations requires that *"When preparing for port planning, environmental impact assessment shall be conducted according to the law. It shall also comply with the procedures, contents and depth requirements of the environmental impact assessment prescribed by the state."*[12] The aforementioned "law" refers to the Environmental Impact Assessment Law and the Regulations on Planning Environmental Impact Assessment.

The provisions of the Environmental Impact Assessment Law and the Planning EIA Regulations on the scope and procedures of the EIA apply to all planning activities, and no special provisions are made for port master planning.

2.2 AIR POLLUTION ASSESSMENT IN CHINESE PORT EIAs

Air pollution assessment is one part of the EIA process as well as for port EIAs. Generally, for an EIA, it is required to analyze, forecast, and evaluate all possible environmental impacts. As a basic requirement for the Planning EIA, Technical Guidelines for Planning Environmental Impact Assessment General Principles requires evaluation agencies to comprehensively assess all possible environmental impacts (including direct impacts, indirect impacts, short-term impacts, long-term impacts, various possible regional, comprehensive, and cumulative environmental impacts).[13] However, the scope of environmental impacts required for port EIAs has gradually expanded over time.

Technical Key Points of Environmental Impact Assessment for the Port Master Planning (the TKP), issued in 2012, requires focusing on identifying long-term, direct, irreversible and cumulative impacts, and paying attention to indirect impacts. The 2018-issued *Technical Specification for Environmental Impact Assessment of Traffic Planning, Part 2: Overall Port Planning (JTT1146.2-2018)* requires identification of environmental impacts that may lead to conflicts resulting from deterioration of environmental functions and resource and environmental utilization, including long-term, direct, irreversible, comprehensive, regional, and cumulative impacts, as well as indirect effects.[14] It can be seen that the assessment of possible indirect impacts caused by port master planning implementation has been strengthened in the EIA process.

Policymakers have been gradually aware of the importance of integrating mobile source emissions into port EIAs. In the 2012 TKP, the dust of bulk cargo ports, and oil and gas in tanker terminals, were the focus of air pollution environmental impact assessments. In terms of mobile sources, the assessment of ship exhaust is only required for EIAs of busy inland river ports, while air pollution from the mobile sources in other types of ports (e.g., seaports) is neither identified as a major source of pollution, nor considered in the air pollution assessment. In the EIA Technical Specification for Port Overall Planning, issued in 2018, however, the importance of mobile source emissions in port planning EIAs has been enhanced. Ship exhaust has been listed as the third important evaluation target after dust and oil and gas. Appendix D of the port overall planning EIA indicator system lists the total amount of sulfur dioxide and nitrogen dioxide emissions (t/year) from ships, cargo trucks, and port machinery equipment as pollutant discharge evaluation indicators.

2.3 CHINA'S POLICY MEASURES FOR TACKLING PORT AND SHIPPING-RELATED AIR POLLUTION

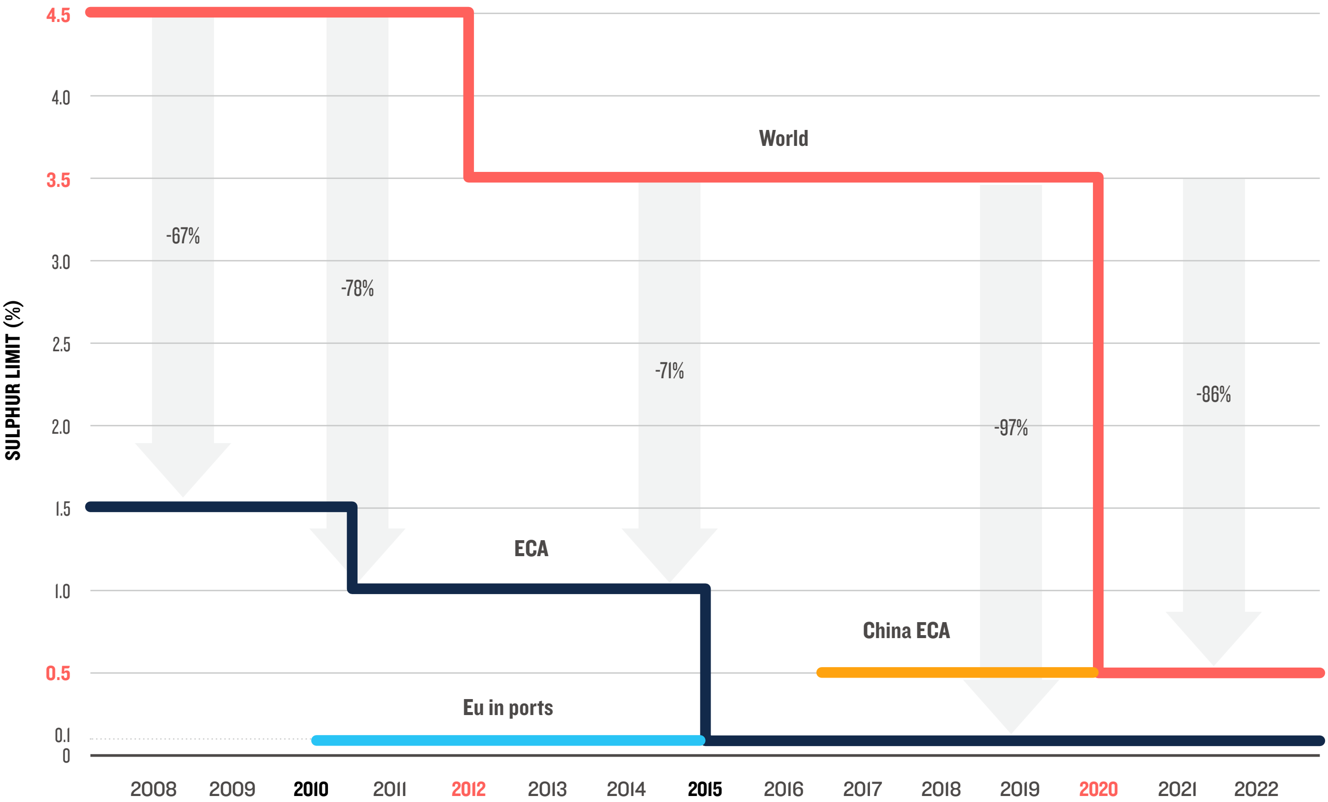
Port air pollution mainly comes from three sources: shipping emissions, port operations and cargo handling, and truck transportation. In recent years, with effective industrial transformation and upgrading, tightening coal-burning and on-road motor vehicle pollution control, emissions from off-road mobile sources such as vessels have gradually stood out and gained more and more attention. The Chinese government has issued a series of policies to combat air pollution from ports and shipping.

2.3.1 IMPLEMENTING DOMESTIC SHIPPING EMISSIONS CONTROL AREAS

In 2016, China introduced the Domestic Emission Control Area (DECA) regulations, which mandate the use of lower sulfur marine fuel, in stages. The regulation was first implemented at three key port areas (Circum-Bohai Sea, the Yangtze River Delta and the Pearl River Delta) and requires that all ships at berth use 0.5 percent sulfur fuel. Beginning in January 2019, all ships operating in China's territorial waters (12 nautical miles (nm) from shore) have to use 0.5 percent sulfur fuel; and since January 2022, ocean-going ships operating in Hainan waters must use 0.1 percent sulfur fuel. The regulations also require all inland ships to use diesel fuel with no more than 10-ppm sulfur, the same as motor vehicle fuel[15].

China's DECA policies are largely based on the standards developed by the International Maritime Organization (IMO) under the International Convention for the Prevention of

FIGURE 2. CHINA'S DECA, IMO ECA AND THE WORLDWIDE SULFUR FUEL LIMIT



Fuel type	Not regulated = both HFO and distillate are permitted.
Exhaustgas cleaning	Permitted alternative under Regulation 4 to achieve any regulated limit.
Particulate Matter (PM)	No limit values.

Pollution from Ships (MARPOL). The DECA regulations introduced in 2016 essentially pulled ahead the implementation of the IMO global requirement of 0.5% percent sulfur fuel for all oceangoing vessels, which went into effect in January 2020, by 3 to 4 years at China's key port regions. And the expanded 2019 DECA regulations were one year ahead of the 2020 global requirement. The fuel sulfur content in the international ECAs has been limited to 0.1 percent since 2015.

2.3.2. ENCOURAGING ONSHORE POWER

Onshore Power Supply (OPS) provides shore-side electrical power to ships at berth while their main and auxiliary engines are shut down. Shore power saves consumption of fuel that would otherwise be used to power vessels while in port, and eliminates the air pollution associated with consumption of that fuel. Under the DECA regulations, ships that can connect to shore power have been required to use shore power beginning in July 2019, and all cruise ships calling at China's ports must plug into shore power beginning Jan 1, 2021. Chinese-flagged inland ships and coastal ships (except tankers) built since 2019 and 2020, respectively, shall be shore power-capable and start using shore power beginning in 2022. According to the MOT-released port shore power deployment plan, China has set aside funding to build 493 sets of onshore power infrastructure at seaports and inland ports (366 and 127 sets respectively) by 2020 to enable ships to use shore-side electricity while at berth. Meanwhile, local governments like Shenzhen are providing OPS construction subsidies and incentives for using OPS.

TABLE 2. LNG VESSELS IN CHINA TILL 2019 [17]

TYPE		NUMBER	TOTAL
LNG-Powered		110	285
Dual Fuel		175	
Retrofit	Original Fuel Engine	46	285
	Update Engine	72	
New-built		167	

2.3.3 ELECTRIFYING PORT EQUIPMENT

At the same time, large Chinese ports are undergoing upgrades to electrify port cargo handling equipment, particularly cranes. Older diesel drayage trucks have also been replaced with liquid natural gas (LNG) or electric drayage trucks.

Onshore power facilities and electric port equipment, if they are powered by renewable energy, could substantially improve air quality around port areas, and reduce CO_2 and black carbon emissions from shipping and port activities.

2.3.4 PROMOTING LNG IN THE SHIPPING INDUSTRY

During the 12th and 13th Five Year Plans (FYP), China focused largely on promoting LNG as the low-emission marine fuel alternative. Seventy-four LNG bunkering infrastructures were planned along the Yangtze River, West River (a part of the Pearl River system), and Jinghang Canal. More than 280 LNG-powered vessels were constructed or retrofitted in China, as listed in Table 2. While there are hundreds of LNG-powered inland ships in operation on the Yangtze River, this effort faces significant challenges, most notably public concerns over the safety of LNG bunkering infrastructure, which has significantly slowed down the construction of bunkering infrastructure and the deployment of vessels.[16]

2.3.5 SHIFTING TRANSPORTATION MODES

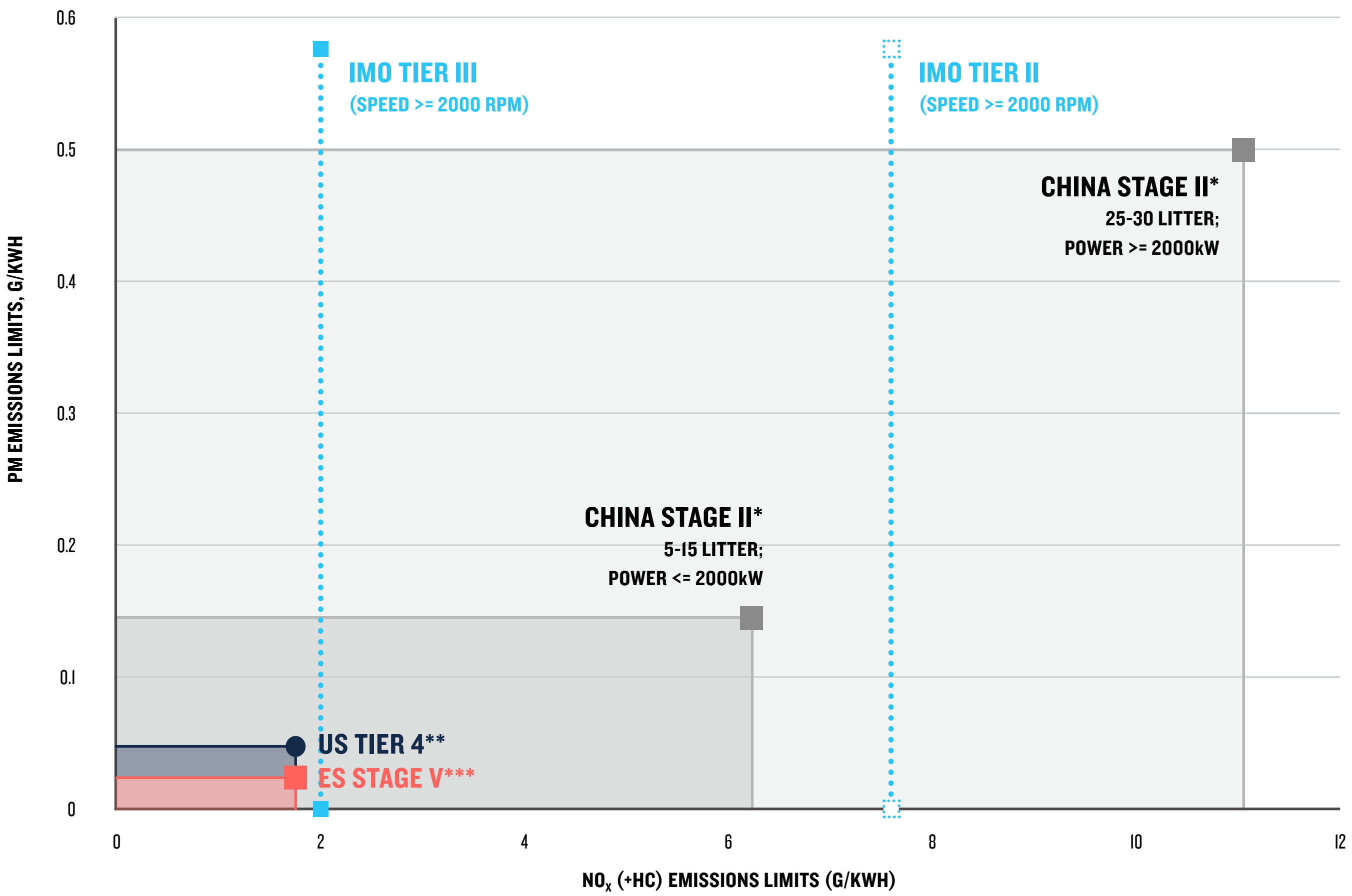
One of the major strategies outlined in The Action Plan for Winning the Blue Sky War is to adjust the freight transportation structure and shift the mode of transportation from road to both rail and water. China will steadily increase the amount of railway freight, promote at-dock rail/ship-ship transshipment, and improve connections between at-dock rail and major railways/terminal storage yards. By 2020, major ports along the Yangtze River will be connected with port railways.

2.3.6 UPGRADING ENGINE EMISSIONS STANDARDS FOR DOMESTIC VESSELS

Currently, control of NO_x emissions from ships mainly relies on setting engine emissions standards. China's Phase I emissions standards for engines on inland, coastal, sea-river ships and fishing vessels began implementation on July 1, 2018. The NO_x and hydrocarbon (HC) limit of China's Phase I marine engine standard is at least three times as high as the China V[i] limit for trucks. Since September 1, 2018, the diesel engines of imported vessels and Chinese international vessels that are engaged in domestic waterway transportation are required to meet the requirements of Tier II NO_x emissions by MARPOL 73/78 Annex

[i] Emission standards for new heavy-duty truck and bus engines in China follow the European precedent, and are known as China I, II, III, etc. China V standards (similar to Euro V) apply to all sales of new diesel and gasoline vehicles nationwide in July 2017.

FIGURE 3. MARINE ENGINE EMISSIONS STANDARDS



Emission standards depend on engine rated speed, displacement per cylinder or rated power; rpm = revolution per minute

* Standards for PM and NOx+HC, to take effect in 2021.

** Standards for PM and NOx, for engines with rated power >= 600kW and <3,700kW; phased in from 2014 to 2017

*** Standards for PM and NOx, for engines with rated power > 300kW; phased in 2019-2020.

VI.[ii] On July 1, 2021, the second phase marine engine emissions standard will be implemented. In the EU and the U.S., inland and domestic ships are subject to much more stringent NO_x standards. New oceangoing vessels (OGVs) operating in the U.S. ECA (and in the North Sea and Baltic Sea ECAs in 2021) also need to meet more stringent NO_x limits (IMO Tier III standards). These standards only apply to new ships. Ships must also install emissions control devices, or switch to alternative fuel engines (like LNG) to meet the stricter IMO Tier III NO_x requirements. These technologies require significant upfront costs, as well as some operational costs.

With all these measures and practices in place, port-related air pollution in China has been decreasing remarkably. In 2018, the emissions of SO_x and particulates from ships in the DECA of Bohai Sea (Beijing-Tianjin-Hebei), Yangtze River Delta and Pearl River Delta decreased by 33% and 22% respectively compared with 2015.[18]

[ii] The NO_x emission limits of Regulation 13 of MARPOL Annex VI apply to each marine diesel engine with a power output of more than 130 kW installed on a ship. Annex VI (revised) implements a "three-tier" structure for new engines. For Tier II, NO_x emission levels for a diesel engine installed on a ship constructed on or after January 1, 2011, would be reduced to 14.4 g/kWh. For Tier III, NO_x emission levels for a diesel engine installed on a ship constructed on or after January 1, 2016, would be reduced to 3.4 g/kWh, when the ship is operating in a designated ECA. Outside a designated ECA, Tier II limits apply.

3

U.S. AND EU REGULATORY FRAMEWORK ON EIA FOR PORTS

In the United States and European Union (EU) countries, port EIAs require the assessment of the environmental and social impacts of port development on a wide range of issues, including air quality, and mobile sources assessment is an essential part of it. Pending the proposed development, a systematic approach is taken to estimate air pollutant emissions from port-related emissions sources, including e.g. vessels, cargo handling equipment, heavy-duty vehicles, harbor crafts, and rail locomotives. On this basis, the sustainable development of the port is supported by the combination of the port environmental impact assessment and the environmental permit.

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3.1 U.S. REGULATIONS RELATED TO EIAS FOR PORTS

3.1.1 THE NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

In the United States, President Nixon signed the National Environmental Policy Act (NEPA) on January 1, 1970, as his first official act of the new green decade. About half of the U.S. 50 states followed, including California with the California Environmental Quality Act (CEQA)[19]. NEPA is the foundation of environmental impact analyses in the U. S.

The Council on Environmental Quality (CEQ) in the White House, which was created shortly after NEPA's enactment, issued non-binding guidance on how to implement the law. After seven years of experience and amid complaints about the unnecessary delay and paperwork, President Carter issued binding regulations to replace the earlier guidance. It aimed to streamline the law's application — reducing paperwork and delay while emphasizing environmentally protective results. Now, EIA practices apply in all 50 states.

Construction projects in the United States that are funded in whole or in part with federal (not state) funds, or projects that will have an impact on federal lands or waters (such as major rivers and the ocean), must be analyzed under NEPA. Most major port projects, as large transportation infrastructure projects, will be subjected to NEPA because they entail funding, permitting, or other approval by a federal agency.

NEPA requires the lead agency on a project to take a "hard look" at the project's environmental consequences and to compare feasible alternatives that may reduce those consequences. On a port project, this would include analyzing "upland" effects such as increased local diesel truck traffic as a consequence of a port expansion or dredging project.

3.1.2 THE EIA PROCESS

There are three levels of compliance with NEPA: (1) an Environmental Impact Statement (EIS) — the most thorough analysis, of which several hundred are prepared annually; (2) an Environmental Assessment (EA), a much briefer document of which some dozens of thousands are prepared each year; and (3) a Categorical Exclusion, which encompasses categories of actions which have been determined in advance to have no significant environmental impacts, either individually or cumulatively.

An EIS must contain a statement of purpose and need for the proposed action, a discussion of alternatives, a discussion of the affected environment, public involvement, and a discussion of the environmental consequences of the proposed activities and the alternatives. NEPA applies both to individual projects and to policies, plans, and programs.

The alternatives discussion is described as the "heart" of the EIA process. The document must objectively evaluate all "reasonable alternatives," devoting "substantial treatment" to each alternative, including a "no action" alternative.

The EIS must also discuss mitigation, which are means to reduce or eliminate any adverse environmental impacts should the action go forward. The discussion must include both direct impacts (those caused by the action which occurs at the same time and place) and indirect impacts (which are those caused by the action but later in time or located in distance but which are still "reasonably foreseeable"). The latter category includes growth-inducing impacts.

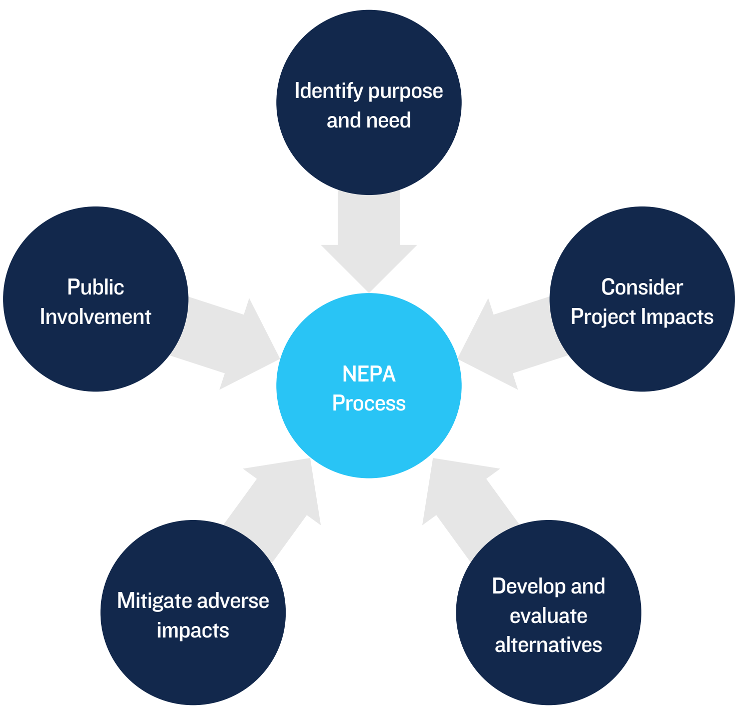
The EIA document must also discuss cumulative impacts, which are those that result from the action when added to other past, present, and reasonably foreseeable future actions (regardless of what entity undertakes the action). These can result from individually minor but collectively significant actions. With respect to ports, the air emissions from the ships, trucks, trains, and dock equipment serving the port would be an example of cumulative impacts.

In the EIA process, agencies have different roles. The agency proposing the action (or with the power to approve it) is the lead agency in preparing the EIA document. Agencies with jurisdiction or with special expertise can be cooperating agencies, which assist the lead agency. Any agency that comments on the EIA document is a commenting agency. CEQ oversees the government-wide NEPA process. The U.S. Environmental Protection Agency (EPA) is delegated the responsibility of publicly evaluating every other agency's EISs by CEQ.

An EIS may be prepared by the lead agency itself or by an outside contractor chosen solely by the lead agency. There is a conflict of interest provisions to ensure that a contractor has no interest in the outcome of the EIA process, such as contingent remuneration.

Procedurally, the NEPA process starts with scoping, wherein the lead agency invites the public and other agencies to

FIGURE 4. NEPA EIS COMPONENT [20]



comment on what should be studied in the EIS. Then, a draft EIS is prepared, and a public comment period follows. Then, based on the comments, the lead agency revises its document and prepares a final EIS, which is released for a further comment period of at least 30 days. Following that, the lead agency prepares its Record of Decision (ROD) in which it describes its decision, what attention was paid to the EIS and what mitigation and monitoring measures are adopted to ensure follow up to what was decided.

According to a survey implemented by the American Association of Port Authorities (AAPA), U.S. port and private sector partners projected to spend $154.8 billion on port-related infrastructure, with an additional $24.8 billion of investment by the federal government in U.S. ports through 2020.[21] Considering all of these ports-related planning and investments, the U.S. EPA released a National Port Strategy Assessment in 2016 to guide the assessment of mobile source emissions at U.S. port areas and provide decision-makers with strategies and technologies to reduce air pollution and greenhouse gases at U.S. ports.

3.1.3 CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

In California, projects like port development are analyzed under the California Environmental Quality Act (CEQA). CEQA patterns itself after NEPA but with a greater obligation on the part of decision-makers to select the environmentally preferable alternative. NEPA is often described as procedural (which is to say, there is full disclosure of impacts but no obligation to avoid them) while California's CEQA is substantive (which means there exists a statutory obligation to avoid adverse impacts). CEQA requires that significant environmental effects of a project be mitigated if feasible. In practice, this often means that a project will be more expensive than the project proponent would like. For example, if upland environmental effects such as increased diesel truck emissions will occur, mitigation in the form of cleaner trucks or zero-emissions cargo movements may be required. These mitigation measures are legally enforceable in court by the lead agency in charge of the project or by citizens. California can adopt more stringent emission standards for new engines or vehicles (subject to a waiver from EPA) and set fuel specifications.

3.1.4 REQUIREMENTS FOR PORTS AIR POLLUTION ASSESSMENT

The federal Clean Air Act (CAA) and the NEPA provide legal authority to regulate and mitigate the impacts of emissions from goods movement in the U.S. The CAA is designed to protect public health and welfare from different types of air pollution. It establishes air quality standards for certain pollutants, including ozone, particulate matter, nitrogen dioxide, sulfur dioxide, and carbon monoxide. Regions that record air pollution levels above these standards are called "nonattainment" areas. States with designated nonattainment areas must develop enforceable air quality plans, or State Implementation Plans (SIP), that identify the emission reductions needed to attain the standards and the control measures that will achieve those reductions. For the port industry, significant aspects of the CAA include regulations on diesel engines, marine vessel loading operations, paint coatings, and emissions from vehicles and many types of port equipment.[22,23]

The CAA imposes requirements on transportation planning including port expansion or construction planning. It requires that federal funded or approved highway, seaport, airport, and rail projects conform to SIP emission projections to avoid creating new air quality violations, worsening existing violations, or delaying timely attainment of air quality standards. EPA partners with other federal agencies to set conformity policy via regulations and to enforce that policy as infrastructure proposals are approved.

By providing information, incentives, and financial assistance, EPA is working to encourage firms to adopt clean technologies that meet or surpass regulatory standards. The National Clean Diesel Campaign is an umbrella initiative that aims to reduce diesel emissions from various sectors, including trucks, locomotives, ships, and cargo handling equipment. EPA's Sector Strategy Program also works with industry to achieve sectorwide environmental goals. For example, EPA has encouraged ports to measure their environmental impact with emissions inventories and to deploy environmental management systems (EMS).

California has an extensive program to assess and cut the health risk from goods movement sources, as well as to reduce the emissions that contribute to high regional ozone and $PM_{2.5}$

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levels. California Air Resources Board (CARB) developed plans to update trucks, harbor craft, and cargo equipment and adopted regulations to minimize emissions and community health impacts[24]. CARB rules also require the use of low sulfur fuel for ships ahead of the IMO requirements and use of shore power (or equivalent alternatives) to cut ship emissions at dock.

A number of ports also have voluntarily implemented plans to manage air quality and reduce their environmental footprint. Ports have implemented a range of strategies, such as encouraging the use of shore power, increasing access to rail, and using low sulfur fuels among other strategies.

At the ports of Los Angeles and Long Beach, collectively the busiest ones in the U.S., neighborhood community groups and NRDC challenged the ports' compliance with CEQA on several large expansion projects in the early 2000s. The most important environmental issue was air pollution from port-serving ships, trains, trucks and other vehicles. Air pollution at the ports, principally a function of diesel particulate matter, is typically assessed through emissions inventories that are conducted by a combination of modeling and testing.

As a result, the ports created a Clean Air Action Plan[25] that covers all forms of the cargo movement in the ports, including ships, trucks, trains, and yard equipment. That plan calls for aggressive port action through leases, tariffs, and incentives to clean up diesel sources and limit the impacts of port expansion projects. The plan has helped reduce diesel particulate emissions in the ports by 87 percent from 2006 to 2016, while port throughput has increased by 10% during that time. The ports have also been sensitized to the need for strict CEQA compliance in the future.

3.1.5 PUBLIC PARTICIPATION: ENHANCING ACCOUNTABILITY

NEPA also outlines a public involvement process for local communities to ensure that the health impacts of port related projects are properly considered and mitigation efforts are implemented. NEPA requires that environmental analyses be made available to the public in full, electronically and in hard copy. Public comments are solicited and a public hearing is usually held. All public comments are responded to in writing by the lead agency. When the agency makes its final decision, the decision can be challenged in court. To further improve community involvement, EPA developed the Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses to educate Federal agencies on ways to address environmental justice concerns and involve local communities.[26]

After the decision, any person with standing may challenge the decision in court, asserting that, based on the record before the decision-maker, the decision was arbitrary and capricious. If the plaintiff is successful, the matter is remanded to the lead agency to correct its errors. As a practical matter, only a small proportion of NEPA documents are challenged in court, but the prospect of independent, impartial review helps immensely in ensuring the integrity of the NEPA process.

3.2 EU REGULATIONS RELATED TO EIAs FOR PORTS

3.2.1 BRIEF INTRODUCTION TO THE EU EIA DIRECTIVE

The EU Directive on Environmental Impact Assessments, or EIA Directive, which governs EIA practices in the European Union, was first introduced in 1985 and amended several times since. In 2001, the Strategic Environmental Assessment (SEA) Directive was introduced as well. The EIA Directive applies to a wide range of public and private projects, as defined in its Annexes I and II. All projects listed in Annex I are considered as having significant effects on the environment and require an EIA; for all Annex II projects, having an EIA is at the discretion of the relevant national government. Port development is included in Annex I, while smaller projects at a port may fall under Annex II.[27,28]

At the EU level, specific policies or requirements for EIA studies in port environments do not exist. Port activities and expansions are considered part of the transportation and infrastructure sectors and, especially, part of multimodal trans-European networks. EIAs and environmental management relating to ports must comply with all the general requirements of the relevant legislation and, in particular, must pay attention to "environmentally sensitive areas," as defined in EU regulations. As ports are generally located close to populated and marine sensitive areas, any port development also has to be considered from a holistic perspective on coastal planning, taking into account socio-economic and environmental needs and constraints of the surrounding coastal zone. In addition, for transportation-related projects, the key objectives set by the European Commission are: (a) sustainable and safe mobility, (b) environmental protection, (c) comparison of modes of transportation based on their environmental impacts, (d) optimal use of existing facilities, and (e) interoperability. Performance indicators for environmental sustainability should be specified. A Code of Conduct (ESPO, 1995) provides a quality framework for a programmed action with respect to the protection of the environment within port areas.

Large ports, depending on the passage of vessels of a certain tonnage, fall under Annex I of the EIA Directive. For smaller ports, Annex II has to be applied. This Annex indicates that "construction of roads, harbors and port installations, including fishing harbors (projects not included in Annex I)", must be subject to an EIA if a determination is made either on case-by-case examination or on the basis of thresholds and criteria set by the Member State. Annex III of the Directive sets out selection criteria that must be taken into account when making a case-by-case study or when setting thresholds and criteria.

Based on the overarching framework provided by the EU EIA Directive, each EU member country should make or revise its own EIA legislation and policies to implement EU Directives.[iii] These country-specific EIA regulatory frameworks and processes can still differ considerably between EU countries. An IMPEL study (2012) found that:[29]

- Guidelines for screening of Annex II projects on whether an EIA is required exist in several (hence not all) EU countries.
- Authorities responsible for EIA procedures can be at the national, regional, or local level, as well as statutory bodies where a slight majority for the regional level can be observed.
- In approximately 50 percent of the countries, scoping for the environmental report is carried out on a mandatory basis, while guidelines for scoping and the EIA process exist in several countries. Apart from competent authorities, participation of the public in mandatory scoping exists in several countries.
- In nearly all EU countries, investigations on the environmental impacts of the construction phase have to be carried out, while in approximately 75 percent of

[iii] Important to note that the EIA Directive sets the minimum standards/requirements, that EU countries will have to comply with through their national legislation. They can not go below, but can always exceed the Directive's requirements.

EU countries, the environmental impacts of potential accidents/incidents have to be investigated.

- The evaluation process of the submitted EIA report may sometimes involve specially appointed committees or independent experts in addition to the competent authority.
- In most EU countries, the EIA entails recommendations on monitoring. In about two-thirds of countries, these recommendations are subsequently included in the development consent as obligations or conditions.

The EIA Directive was updated in 2014 for reasons including insufficient operation of the screening process (Annex II), leading some EU countries to mandate EIAs, while others would proceed without any EIA; insufficient quality and analysis of the assessments; and the risk of inconsistencies with other EU Directives, including the time length of an EIA, sometimes leading to either drawn-out processes or very short ones which give insufficient room for public consultation.[30]

In addition to the more general EIA Directive, the European Union has a number of specific policies, strategies, and laws governing various aspects of maritime transportation and infrastructure. One example is the European Monitoring, Reporting and Verification (MRV) initiative of 2015, which regulates carbon emissions from ships arriving at or departing from ports under the jurisdiction of an EU Member State. Shipowners and operators are required to comply with rules for monitoring, reporting, and verification (MRV) of carbon emissions. The submission of a monitoring plan was due by August 31, 2017, marking the first compliance deadline.[31]

3.2.2 REQUIREMENTS FOR PORT AIR POLLUTION ASSESSMENT

The European Air Quality Directive, adopted in 2008, is the key directive governing air quality in the European Union. It sets objectives for several air pollutants that are harmful to human health. It also requires the EU Member States to monitor and assess air quality to ensure that they meet these objectives, report to the European Commission and the public on the results of this monitoring and assessment, and prepare and implement air quality plans containing measures to achieve the objectives. Other potentially relevant directives for port developments include the Directive on Emissions from Engines to be Installed in Non-Road Mobile Machinery, the Directive on the Sulphur Content of Liquid Fuels, and the Directive on VOC Emissions Resulting from Storage and Distribution of Petrol.

All EU directives must be transposed into national legislation, which will designate which authority or body is responsible

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for each of these tasks, while countries can also choose to adopt stricter thresholds/limit values than those included in the Directive. The Air Quality Directive sets limit values for particulate matter (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead, benzene, and carbon monoxide, with these limit values informed by guidelines set by the World Health Organization (WHO).[32]

Pending the development's size and significance, different types of EIAs can be conducted, such as the rapid EIA, which may be undertaken for projects that are likely to cause limited adverse effects. This quick process involves the collection of one-season data, broad identification of impacts and prediction of impacts with general methods. A comprehensive EIA will be required for projects likely to cause a range of significant adverse impacts whose extent cannot be determined without a detailed study. Projects resulting in impacts on the development of an entire region may require a Strategic Environmental Assessment to be conducted in advance.[21]

As part of the scoping process for the EIA study, responsible authorities may determine specific air quality (emissions dispersion) modeling and impact assessment requirements based on whether air emissions from the project are expected to potentially affect nearby sensitive residents or habitats. For the Port of Rotterdam in the Netherlands, for instance, recent port expansions have been located quite far from residential areas; it is the potentially adverse impact of increased NO_x emissions on nearby sensitive habitats that has been a limiting factor for some of its proposed developments. Different dispersion models are normally used to predict the dispersion of emissions from stationary sources (such as stacks) versus the emissions from moving objects (such as traffic). Furthermore, it is important to have a sufficiently continuing and reliable set of data available for background air quality levels (existing emissions at the impacted location) and meteorological data. Countries like the Netherlands have developed their own preferred air quality models, including comprehensive data sets, to assess air quality impacts from proposed developments.

3.2.3 FOLLOW-UP MECHANISM: MONITORING IN PORTS

At the end of the EIA process, the relevant authorities will make a decision as to whether the project can go ahead or not, and note any conditions associated with it. This decision must be made public, as do the principal arguments upon which the decision was based (including information on the process of public participation) and any measures that must be taken to reduce the adverse effects of the project. The conditions associated with the approval of the EIA are included in the environmental license for the project and generally include specific monitoring and reporting requirements. Reference measurement methods for air pollutants are available through Europe's EN standards (e.g. EN 12341 for the measurement of PM_{10}). The European Standards (ENs) are documents that have been ratified by one of the three European Standardization Organizations; CEN, CENELEC or ETSI, and recognized as competent in the area of voluntary technical standardization.

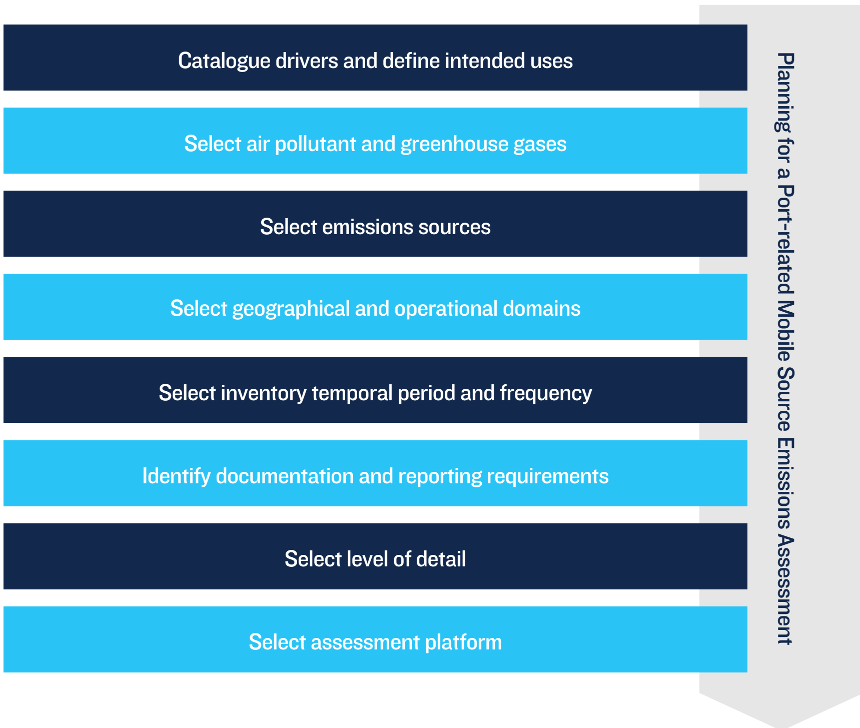
To ensure compliance, licenses often require proof that ambient air quality standards are not breached. However, attributing a breach of such a standard to a particular source may not always be straightforward. Licenses may therefore also include actual limits on the rate of emissions of one or more pollutants of concern and a requirement that operators of sources monitor emission rates, or have them monitored on their behalf. Such monitoring must be carried out within a quality assurance regime to ensure that the data obtained is valid and appropriate to the nature and size of the source and the pollutants under consideration.[33]

4

MOBILE SOURCE ASSESSMENTS AT PORTS

In this section, general process and approaches used for mobile source assessment will be introduced to help improving port emissions assessment in China's ports EIA practices. The contents of this section are mainly from two references. One is *Port Emissions Toolkit Guide No.1: Assessment of port emissions,* which was published in 2018 by GloMEEP cooperative initiative and The International Association of Ports and Harbors (IAPH), The other one is *National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports,* which was published by U.S. EPA in 2016.

FIGURE 5. PLANNING STEPS FOR A PORT EMISSIONS ASSESSMENT [35]



4.1 PLANNING STEPS

To maximize success and minimize the effort of conducting a port emissions assessment, the Port Emissions Toolkit[34] recommends following a series of planning steps before starting the actual assessment. The steps are illustrated in Figure 5 and major steps are further discussed in the following sections.

Besides the above planning steps, the U.S. EPA's National Port Strategy Assessment suggests considering the following questions when assessing strategies for a specific port area.[36]

- What is the type and size of the port?
- What source sectors are the most significant diesel emitters at the port?
- Is there a port-specific emission inventory or clean air plan available to inform decisions?
- How old are the diesel fleets of each port sector?
- Is there an existing forum for stakeholder participation?

4.2 MOBILE SOURCE SECTORS ANALYZED IN PORT EIAS

The U.S. EPA defines mobile sources as motor vehicles, engines, and equipment that move, or can be moved from place to place. Mobile sources include vehicles that operate on roads and highways, as well as non-road vehicles, engines, and equipment. According to the U.S. EPA Ports Initiative, emissions from port-related trucks, locomotives, cargo handling equipment, harbor craft, and ocean-going vessels need to be assessed.[37] The National Port Strategy Assessment published by the EPA focuses on the potential of strategies to reduce emissions from diesel-powered vehicles and equipment and assesses five major mobile source sectors as below.

4.2.1 DRAYAGE TRUCKS

Drayage trucks are combination short-haul trucks that move cargo into and out of ports. Drayage trucks typically travel short distances to and from the port to a nearby rail yard or distribution center. This truck activity typically involves significant idle or creep time to enter and exit a port as well as load or unload containers or other cargo. In the U.S., drayage trucks are generally older than the average truck fleet, since long-haul trucking firms tend to have newer fleets and a much faster turnover rate.

4.2.2 RAIL

The rail emissions sources in the U.S. ports EIA assessment usually include switcher and line-haul locomotives. Switchers move rail cars short distances within a rail yard, and line-haul locomotives travel out of the port to distant locations. Switchers connect individual rail cars to form the trains that line-haul locomotives move out of the port.

4.2.3 CARGO HANDLING EQUIPMENT

Cargo handling equipment (CHE) is located on a port and moves cargo on and off ocean-going vessels (OGVs) and harbor craft. CHE moves cargo around the port so that it can be loaded onto trucks and rail cars. There are many different kinds of CHE, including forklifts, cranes, and bulk handling equipment (e.g., tractors, loaders, etc.). At major U.S. ports, CHE is gradually being switched to electric or hybrid. The assessment focuses on a subset of diesel-powered CHE, specifically yard tractors, rubber tire gantry (RTG) cranes, and container handlers (top picks and side picks).

4.2.4 HARBOR CRAFTS

Harbor crafts assist in moving OGVs around the harbor, move cargo and people into and out of the port harbor area, and provide fuel to OGVs; they also transport crew and supplies to offshore facilities. Harbor crafts are vessels with engines less than 30 liters per cylinder and are classified as Category 1 and 2 vessels in the U.S.. There are many different kinds of diesel-powered harbor crafts, including commercial fishing boats, government vessels, and dredges.

4.2.5 OCEAN-GOING VESSELS

OGVs move cargo and people into and out of a port and typically travel long distances to or from foreign ports. They may also travel to or from other domestic ports. OGVs are vessels with engines of 30 liters per cylinder or more (i.e., Category 3 vessels); OGV ship types considered in the ports assessment are described in Table 3. Both propulsion and auxiliary engine activity needs to be assessed for OGV diesel emissions.

TABLE 3. OCEAN-GOING VESSEL SHIP TYPES FOR ASSESSMENT

SHIP TYPE	DESCRIPTION
Auto Carrier	Self-propelled dry-cargo vessel that carries containerized automobiles
Bulk Carrier	Self-propelled dry-cargo ship that carries loose cargo
Container Ship	Self-propelled dry-cargo vessel that carries containerized cargo
General Cargo	Self-propelled cargo vessel that carries a variety of dry cargo
Passenger	Self-propelled cruise ships
Reefer Self-propelled	Dry-cargo vessel that often carries perishable items
Roll-on/Roll-off (RORO)	Self-propelled vessel that handles cargo that is rolled on and off the ship
Tanker	Self-propelled liquid-cargo vessels including chemical tankers, petroleum product tankers, liquid food product tankers, etc.

4.3 AIR POLLUTANTS AND GREENHOUSE GASES CHARACTERIZED IN PORT EIAS

As stated above, both air pollutants and greenhouse gas emissions are generated from sources used for maritime operations at a port. Port emissions assessments focus on emissions sources related to the movement of cargo. There are broad and diverse emissions sources associated with port operations, but not all source types may be found in every port. Port operations can range from simple cargo handling to industrial and commercial operations intermixed with cargo handling. Some ports handle primarily international marine traffic, while others handle a mix of international and domestic marine traffic.

In most cases, port area stakeholders are primarily concerned with air pollutants that have more near-term and localized impacts. On a local level, NO_x, (associated with ground-level ozone), PM and SO_x (which contributes to PM) are the most critical pollutants affecting air quality around port areas. The adverse health impacts of ground-level ozone and PM are the two most common drivers of air quality initiatives worldwide and will be central to almost any port area effort to reduce air pollutant emissions.

Several countries have air quality standards that define clean air. These standards specify geographical boundaries within which standards must be met. Even though the effects of climate change, such as sea-level rise and extreme weather events, are a general concern for many ports over the long term, climate-related pollutants do not have the same level of local and near-term impacts as pollutants that cause health concerns. As such, most countries do not have specific greenhouse gas emissions targets, or standards, for industries such as ports and the maritime sector. Nonetheless, most nations are committed to addressing climate-related pollutants through the United Nations Framework Convention on Climate Change (UNFCCC), and have or will establish goals for greenhouse gas emissions, which justifies the inclusion of greenhouse gas emissions in port emissions assessments. World Bank and Asia Development Bank (ADB) all require that any projects or activities with greater than 100,000 tons of CO_2 equivalent per year to monitor and reduce the GHG emissions during the project design and operation.[38] The recent ruling by the UK Court of Appeal that plans for a third runway at Heathrow airport is illegal demonstrates that climate pollution would become an increasingly important factor in the EIA for transport proejcts, if countries are serious about the commitments made in the Paris Agreement.[39]

The identification of port-related emission sources focuses on port-controlled or influenced activities, categorized by emissions source category and energy type. It is important to select which pollutants are going to be included in the assessment and their associated units of measure.

4.3.1 CRITERIA AIR POLLUTANTS AND PRECURSORS

Taking the U.S. as an example, criteria air pollutants (CAPs) are those for which either the U.S. federal government and/or the California state government have established ambient air quality standards based on short- and/or long-term human health effects. The U.S. EPA has established national ambient air quality standards (NAAQS) for six pollutants, i.e. NO_x, SO_2, PM (which is further classified by size: PM_{10} and $PM_{2.5}$), O_3, CO, and Lead. NO_x, SO_2 and PM[iv] are commonly selected CAPs for port-related air quality asssement. Although not a criteria pollutant, organic species of volatile organic compounds (VOCs) are often considered along with criteria pollutants because they are chemical precursors for ground-level ozone.[40]

In the U.S., SO_2 was not analyzed for the non-OGV mobile source sectors since these sectors currently use ultra-low sulfur diesel (ULSD), which is a cleaner-burning diesel fuel that has significantly reduced the SO_2 emitted by these sources. SO_2 emissions from OGVs were estimated because, although these vessels use low sulfur distillate fuels at ports (up to 1000 ppm sulfur), further reductions may be gained from the use of even lower sulfur fuels.

4.3.2 CLIMATE CHANGE SOURCES

Carbon dioxide (CO_2), the primary greenhouse gas (GHG) associated with the combustion of diesel (and other fossil fuels), accounts for over 95% of the transportation sector's global warming potential-weighted GHG emissions. Methane (CH_4) and nitrous oxide (N_2O) together account for about 2% of the transportation total GHG emissions. Both gases are released during fuel consumption, although in much smaller quantities than CO_2, and are also affected by vehicle emissions control technologies.

[iv] When specifically discussing diesel emissions, PM is often referred to as diesel PM (DPM).

From a carbon perspective, the relationship of the port's administrative authority to its operating terminals is important in defining the source categories into which various activities fall[41]. Emissions sources for greenhouse gas inventories are treated differently from other air pollutants. Several GHG quantification protocols recommend that the emissions-producing activities should be grouped into three categories, termed "scopes," primarily based on ownership or control of the sources. These scopes have been adapted for ports as follows:

- Scope 1 – Port direct sources. These sources are directly under the control and operation of the port administration entity and include port-owned fleet vehicles, port administration-owned or leased vehicles, boilers and furnaces in buildings, port-owned and operated cargo handling equipment, and any other emission sources that are owned and operated by the port administrative authority.
- Scope 2 – Port indirect sources. These sources include purchased electricity for port administration-owned buildings and operations. Tenant power and energy purchases are not included in this scope.
- Scope 3 – Other indirect sources. These sources are associated with tenant operations and include ships, trucks, cargo handling equipment, rail locomotives, harbor craft, tenant buildings, tenant purchased electricity, and port employee vehicles. For a port with a large number of tenants, this will likely be the largest source of greenhouse gas emissions.

The scopes are illustrated graphically in Figure 6. This figure shows the scopes for a landlord port (cargo operations handled by tenants). For operating ports (where cargo operations are handled by the port itself), the sources shown under Scope 3 in the figure would be considered under Scope 1. Emissions from the generation of purchased electricity will be Scope 2 or Scope 3 emissions, depending on the ownership of the electricity consuming operation; an operating port will have relatively more Scope 2 purchased electricity emissions than a landlord port.

More recently, the quantification of black carbon (BC) particulate matter, which occurs from the incomplete combustion of carbon-based fuels, has become a concern due to its short-lived climate forcing impacts on the acceleration of the melting of ice in the Arctic and Antarctic. Consideration of BC in port emissions assessments is just beginning.

An overview of the most common port-related operational pollutants, sources and their associated health and environmental effects is provided in Table 4.

FIGURE 6. PORT-RELATED GHG EMISSIONS SOURCES BY SCOPE [42]

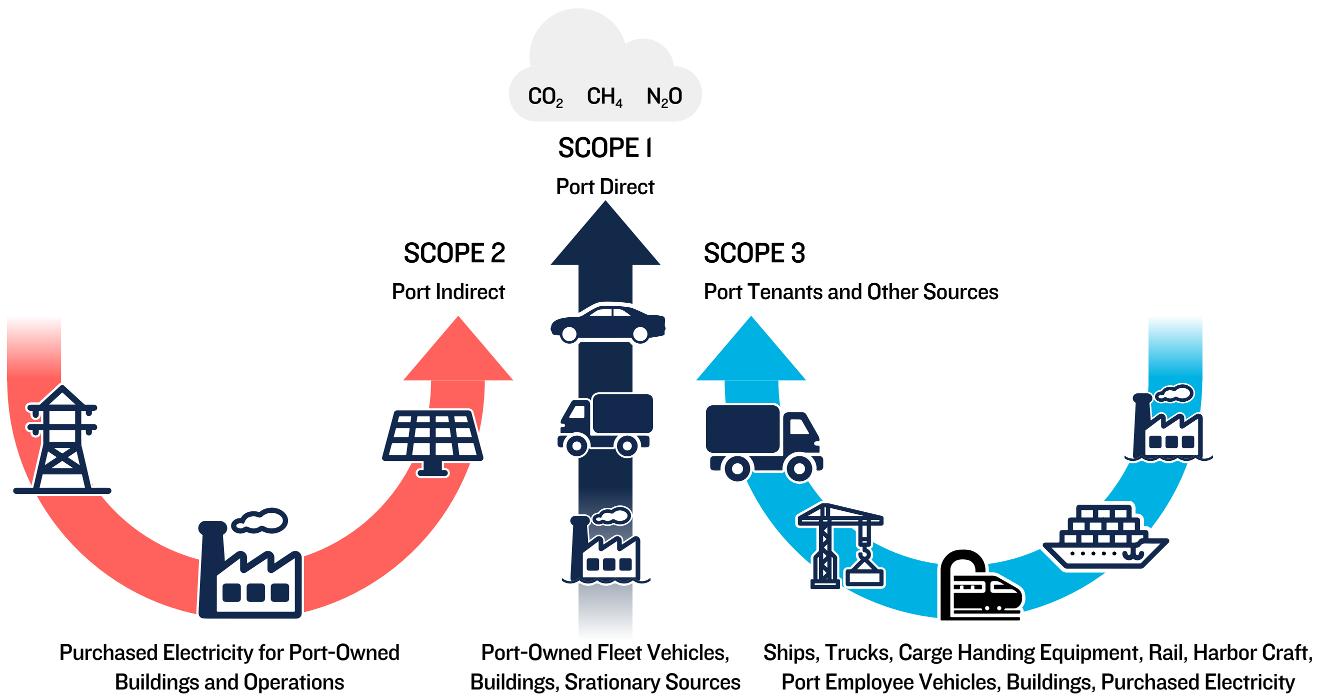


TABLE 4. PORT-RELATED POLLUTANTS, SOURCES AND HEALTH AND ENVIRONMENTAL EFFECTS [43]

AIR POLLUTANT	SOURCES	HEALTH AND ENVIRONMENTAL EFFECTS
NO_x: the generic term for a group of highly reactive gases; all of which contain nitrogen and oxygen in varying amounts. Most NO_x are colorless and odorless.	NO_x form when fuel is burned at high temperatures, as in a combustion process. The primary port-related NO_x sources are from the exhaust from engines that power landside equipment and vehicles, marine vessels, non-renewable energy generation, other industrial and commercial sources that burn fuel.	NO_x can react with other compounds in the air to form tiny particles adding to PM concentrations. NO_x can also bind with VOCs and sunlight to form ground-level ozone or smog. NO_x and VOCs are ozone precursors. Ozone is linked to shortness of breath, coughing, sore throat, inflamed and damaged airways, and can aggravate lung diseases such as asthma, emphysema, and chronic bronchitis.
PM refers to discrete solid or aerosol particles in the air. Dust, dirt, soot, smoke and exhaust particles are all considered PM. PM is typically categorized as Total PM (or just PM) or divided into two smaller size categories: PM_{10}, which consists of particles measuring up to 10 micrometers in diameter; and $PM_{2.5}$, which consists of particles measuring 2.5 micrometers in diameter or smaller. Diesel particulate matter (DPM) is a species of particulate matter important in some jurisdictions.	Airborne PM is a mixture of solid particles and liquid droplets generated in numerous ways. The primary port-related PM sources are from the exhaust of engines that power landside equipment and vehicles, marine vessels, non-renewable energy generation, other industrial and commercial sources that burn fuel. PM can also be generated from large open areas of exposed earth or dirt roads, where vehicles and equipment can disperse PM into the air.	Fine particles are a concern because their very tiny size allows them to travel more deeply into the lungs and enter the bloodstream, increasing the potential for health risks. Exposure to $PM_{2.5}$ is linked with respiratory disease, decreased lung function, asthma attacks, heart attacks, and premature death.
SO_x is a group of colorless, corrosive gases produced by burning fuels containing sulfur.	SO_x is released when fuels containing sulfur are burned in the combustion process. The primary port-related SO_x sources are exhaust from engines that power landside equipment and vehicles, marine vessels, non-renewable energy generation, other industrial and commercial sources that burn fossil fuel.	SO_x is associated with a variety of respiratory diseases. Inhalation of SO_x can cause increased airway resistance by constricting lung passages. Some of the SO_x become sulfate particles in the atmosphere adding to measured PM levels. High concentrations of gaseous SO_x can lead to the formation of acid rain, which can harm trees and plants by damaging foliage and decreasing growth.
VOCs are any compound of carbon (other than CO, CO_2, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) that participates in atmospheric photochemical reactions.	VOCs are generated when fuel is burned in the combustion process. The primary port-related VOCs sources are from the exhaust from engines that power landside equipment and vehicles, marine vessels, non-renewable energy generation, other industrial and commercial sources that burn fuel. Besides, liquids containing VOCs are used by numerous industrial and commercial applications, where they can volatilize into the air.	In addition to contributing to the formation of ozone, some VOCs are considered air toxins, which can contribute to a wide range of adverse health effects. Some VOCs are also considered PM.
CLIMATE CHANGE POLLUTANTS	**SOURCES**	**HEALTH AND ENVIRONMENTAL EFFECTS**
Greenhouse gases (GHGs) that are typically emitted from port-related sources include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Additional gases that are not significantly emitted by maritime-related sources or included in this inventory also contribute to climate change.	GHGs come from both natural processes and human activities. The primary port-related GHG sources are from the exhaust from engines that power landside equipment and vehicles, marine vessels, non-renewable energy generation, and other industrial and commercial sources that burn fuel.	Most climate scientists agree that the main cause of the current global warming trend is the human expansion of the 'greenhouse effect'. Warming results when the atmosphere traps heat radiating from Earth towards space. Certain gases in the atmosphere block heat from escaping otherwise referred to as GHGs. Climate change results in extreme and unusual weather pattern shifts within the Earth's atmosphere.

4.4 GEOGRAPHIC DOMAINS FOR MOBILE SOURCE ASSESSMENTS

The busy roadways and large emission sources at ports may impact local air quality within several hundred metres of the ports. In general, a port-related mobile source assessment should cover all source sectors and geographical areas of interest. This typically includes, at a minimum, the geographical area within the port authority or other areas under the port operator's jurisdiction. It frequently also includes port-related traffic in nearby transportation corridors.

The assessment should cover an entire port, including marine boundaries and landside boundaries where the port-related vessel and freight activities occur. The following describes the U.S. EPA's recommended geographical scope for each mobile source sector.

- OGV: All restricted speed zones, maneuvering areas, hoteling areas, and anchorage zones that are within the port's boundaries, or are used by vessels when calling on the port. For coastal seaports, this could also include transit areas to the international boundary.
- Harbor craft: Typically, the harbor craft geographical scope should be the same as the OGV geographical scope. It should cover all areas where harbor craft support OGVs that call on the port, as well as all other activities by harbor craft that operate out of the port.
- CHE: All areas where CHE activity occurs within the port's boundary.
- Drayage Trucks: All areas where heavy-duty truck activity occurs within the port's boundary, including gates, queues, on-port roads, and loading/unloading areas, in addition to off-port transportation corridors to the first intermodal transfer point.
- Rail: All railyards within the port's boundary and possibly nearby port-related line-haul activity.

4.5 MOBILE SOURCE ASSESSMENTS METHODOLOGY/APPROACH AND MODELS

Usually, a port-related emissions assessment consists of three major parts: an emissions inventory; equipment, activity and emissions metrics; and an emissions forecast.

4.5.1 EMISSIONS INVENTORY

Emissions inventories catalog the various port-related emission sources and their activities, translate those activities into energy consumption levels, and then translate energy consumption into emissions. They provide insight on activities and related emissions of the various source categories, within defined geographical, operational and temporal domains.

Port-related air pollutant emissions inventories are the foundation upon which both emissions metrics and emissions forecasts are built. Port emissions inventories can be developed with different levels of detail, depending on the purpose of the inventory, the data and resources available to compile the inventory, and the timeframe available to complete the work.

Fundamentally, a quantitative emissions inventory is developed using the number (i.e., the population) of vessels, vehicles, and equipment operating in a specific area, along with data on their operational activity combined with appropriate emissions factors.

Separate emissions inventories need to be developed for drayage trucks, rail, CHE, harbor craft, and OGV sectors. For example, drayage trucks and CHE inventories usually are developed using on-road motor vehicle emissions estimation models, such as the U.S. EPA "MOVES,"[44] California's "EMFAC"[45], and Europe's "COPERT"[46]. Recently, U.S. EPA released a draft report, Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emission Inventories.[47] The report has specific information on how to develop inventories for criteria pollutants and precursors, climate-related pollutants, mobile source air toxics, and energy consumption. The document describes the latest, state-of-the-art methodologies for preparing an emissions inventory for mobile source sectors of OGV, harbor craft, CHE, on-road vehicles, and rail.

4.5.2 EQUIPMENT, ACTIVITY AND EMISSIONS METRICS

Equipment, activity and emissions metrics provide context for the inventory. Analysis of inter-related data on equipment, activities, energy consumption, emissions sources, cargo throughput, as well as other indicators, helps create standards to reduce emissions and compare the design and performance of efforts. For example, an emissions metric, such as emissions-per-ton of cargo, can be tracked over time and used to determine whether the ratio improves or worsens. In the case of the latter, the identification of inefficiencies can help inform corrective measures that would decrease the emission intensity of the activity. Manufacturers' emissions reports and equipment duty cycles will also be considered in the assessment.

4.5.3 EMISSIONS FORECASTS

Emissions forecasts are future projections of emissions based on estimates of cargo throughput increases and changes in equipment and operations over time. Forecasts are used to evaluate emissions reduction scenarios; estimate benefits from regulations of port-related sources; identify the potential emissions reduction magnitudes when developing future emissions reduction targets, and support energy efficiency planning.

In general, Baseline and Business as Usual (BAU) scenarios will be developed for the selected port geographical domains, followed by the analysis of various strategies to reduce port-related mobile source emissions. Baseline year emissions inventories provide the base data used in emissions forecasting. BAU scenarios estimate emissions by projecting future trends under the status quo. The baseline year selected can either be the most recent year or any year prior to a major enhancement or expansion of port operations. If past emissions reduction efforts can be documented, it may be decided to choose a baseline year that is before those reductions took place, so that progress made can be quantified. An important consideration is that the further back you go in years, the more likely the required data will not be readily available. This, in turn, can have significant impacts on the resources and time needed to conduct the assessment. The more recent the baseline year selected for the inventory, the greater the likelihood that necessary data is readily available.

For the California CEQA process, it is required to compare baseline conditions with projected future conditions, and, if feasible, the assessment must provide achievable and enforceable measures to mitigate significant pollution increases down to the baseline.

4.6 U.S. EPA NATIONAL PORT STRATEGY ASSESSMENT

In support of the Port Initiative to reduce air pollution and GHGs, the U.S. EPA released a report, *National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports (NPSA)* in 2016. This national-scale assessment was developed to examine current and future emissions from a variety of diesel sources operating in port areas, and to explore the potential of a range of available strategies to reduce emissions from port-related trucks, locomotives, cargo handling equipment, harbor craft, and ocean-going vessels. This assessment can be used as a tool for governments and ports stakeholders to inform their priorities and decisions for port areas and achieve more emissions reductions across the United States.

The EPA developed this national-scale assessment based on estimated emissions from a representative sample of 19 seaports in the United States. In this NPSA, baseline inventories were developed for the year 2011, while emissions projection under the BAU scenario were developed for all pollutants for 2020 and 2030, and the 2050 BAU scenario was developed for CO_2 only. 2011 Baseline emissions models were developed for the five mobile source emissions sectors. Each sector inventory was developed separately using the best available data and methodologies for this national-scale assessment. The totals presented in each of the results sections are the aggregated baseline emissions of all port areas included in this assessment. The NPSA report described the data, methodologies, and results for each of the five sectors. Table 5 summarizes the mobile source emissions sectors included in this assessment, as well as the pollutants and geographic area covered by each sector.

The geographic boundaries of each sector used in this assessment contributed to the relative differences between the amounts of emissions between sectors. Mobile source impacts along port-related transportation corridors (e.g., highways and rail lines) are an important environmental challenge, but this assessment did not focus on corridor impacts. Summarized in Table 6 below, the data sources and methodologies for developing these inventories varied by sector. The assessment relied primarily on existing EPA data and models or other publically available data.

TABLE 5. SUMMARY OF SOURCES, POLLUTANTS, AND GEOGRAPHIC AREAS COVERED BY NPSA

MOBILE SOURCE	TYPE OF EMISSION	POLLUTANT	GEOGRAPHIC AREA COVERED
Truck	On-road Class 8 diesel trucks	NO_x, $PM_{2.5}$, VOCs, CO_2, BC, and select air toxins	All drayage activity within 0.5 km (0.3 mi) from port boundary
Rail	Line-haul and switcher diesel locomotives	NO_x, $PM_{2.5}$, VOCs, CO_2, BC, and select air toxins	All rail activity within 0.5 km from port boundary
CHE	Diesel-powered CHE	NO_x, $PM_{2.5}$, VOCs, CO_2, BC, and select air toxins	All CHE activity assumed to occur on-port
OGV	Diesel propulsion and auxiliary engines	SO_x, NO_x, $PM_{2.5}$, VOCs, CO_2, and BC	All OGV activity within 5 km from port boundary
Harbor Craft	Diesel-powered tugs and ferries	NO_x, $PM_{2.5}$, VOCs, CO_2, BC, and select air toxins	All harbor craft activity within 5 km (3 mi) from port boundary

TABLE 6. SUMMARY OF DATA SOURCES AND METHODOLOGY FOR NPSA BASELINE AND BAU EMISSION INVENTORIES

SECTOR	PRIMARY SOURCES FOR BASELINE (2011)	PRIMARY SOURCES FOR BAU PROJECTIONS (2020, 2030, 2050)
Drayage Trucks	DrayFLEET USACE Waterborne Commerce Statistics FHWA Freight Analysis Framework	2008 Research Triangle Institute (RTI) regional growth rates EPA MOVES2010b model
Rail	EPA National Emissions Inventory Published rail emission inventories	2008 RTI regional growth rates EPA Locomotive and Marine Emission Standards Rulemaking
CHE	Published CHE emission inventories USACE Waterborne Commerce Statistics	2008 RTI regional growth rates EPA NONROAD2008a model
Harbor Craft	EPA National Emissions Inventory	2008 RTI regional growth rates EPA Locomotive and Marine Emission Standards Rulemaking
OGV	EPA C3 Regulatory Impact Analysis USACE Entrances and Clearances Lloyd's Register of Ships Published OGV emission inventories	2008 RTI bunker fuel growth rates EPA C3 Regulatory Impact Analysis EPA North America Emission Control Area Standards

TABLE 7. EXAMPLES OF STRATEGY SCENARIOS ASSESSED IN THE NPSA

MOBILE SOURCE SECTOR	STRATEGY SCENARIO DESCRIPTION
Drayage Trucks	Replace older diesel trucks with trucks that meet cleaner EPA standards and plug-in hybrid electric vehicles.
Rail	Replace older line-haul locomotive engines with cleaner technologies, including electric locomotives.
	Improve fuel economy.
	Replace older switcher locomotive engines with cleaner technologies and Generator Set (GenSet) technology.
Cargo Handling Equipment	Replace older yard truck, crane, and container handling equipment with cleaner technologies, including electric technologies.
Harbor Craft	Replace or repower older tugs and ferries with cleaner technologies, including hybrid electric vessels.
Ocean-going Vessels	Switch to lower sulfur fuel levels that are below EPA's regulatory standards, and liquefied natural gas for certain vessel types.
	Utilize shore power to reduce hoteling of container, passenger, and reefer vessels.

This assessment examined a suite of currently available strategies, including zero emissions (e.g., electric) technologies that can be used to develop voluntary programs to achieve additional emission reductions. Table 7 summarized some of the strategy scenarios assessed in the NPSA. The categories include replacing older diesel fleets; operational improvements to reduce idling, and switching to cleaner fuels, etc. While this assessment included a few strategies to improve operational efficiency at ports, the focus was primarily on assessing technological strategies. EPA continues to believe that operational strategies (e.g., reducing truck or locomotive idling) can be effective at reducing diesel emissions.

As noted in NPAS, the EPA's regulations for new diesel vehicles and equipment are projected to significantly reduce NO_x and $PM_{2.5}$ emissions in the future. However, older trucks and equipment are longstanding fixtures of many port operations, and it will take many years before these fleets turn over to newer technology. Accelerating the retirement of older port vehicles and equipment and replacing them with the cleanest technology will reduce emissions and increase public health benefits beyond what would be achieved without further voluntary actions. Port-related CO_2 emissions are projected to increase from current levels for all mobile sources in future years, in large part due to significant increases in economic trade and activity.

5

CASE STUDIES IN THE U.S. AND THE EU

In order to deal with the problem of port air pollution, the Port of Los Angeles and the Port of Long Beach in the United States and the Port of Rotterdam in the Netherlands pay great attention to the assessment and management of port-related mobile source emissions during the port expansion and operation. Through the establishment of port emission inventory or the application of an air quality model, port pollution emissions are analyzed quantitatively. A clean air action plan is formulated on the basis of quantitative analysis, and the effectiveness of mitigation measures is regularly evaluated for timely adjustment through follow-up environmental monitoring.

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5.1 CASE STUDY OF THE PORT OF LOS ANGELES AND THE PORT OF LONG BEACH

5.1.1 BACKGROUND

The Port of Los Angeles (POLA) and the Port of Long Beach (POLB) are adjacent to one another in the San Pedro Bay but operate separately. Their importance to the U.S. and world trade derives primarily from the container cargo volume they handle. The POLA and POLB are the first and the second largest container ports in the U.S., and together they handle 60 percent of U.S. container traffic.[48]

The Los Angeles area is generally regarded as having the most serious overall air quality problem in the U.S.. National air quality goals are extremely difficult to attain in the Los Angeles area, despite decades of stringent air pollution control efforts and substantial improvements. While two decades ago relatively little attention was paid to air pollution from port-related sources in California, the situation changed dramatically in 2009, when virtually every port-related emissions source—marine vessels, cargo trucks, locomotives, cargo handling equipment, tugs, dredges, and other marine equipment—became subject to mandatory emissions reduction requirements by U.S. ports outside of California. The centerpiece of the air pollution control effort is a series of California state regulatory requirements that have already changed the type of fuel used near the California coast, and which will, within 5 to 10 years, result in the replacement of most existing harbor craft engines, cargo trucks, and cargo handling equipment, as well as alter port operations. The two ports are heavily committed to supporting accelerated implementation of regulatory requirements and to encouraging the development of new technologies.[49]

The California Environmental Quality Act (CEQA) requires state and local agencies to identify significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible. The City of Los Angeles Harbor Department analyzes potential environmental impacts of Port of Los Angeles development projects. If significant impacts are identified, strategies for reducing such impacts are examined. An Environmental Impact Report (EIR) is presented to the Board of Harbor Commissioners before any decision is made on the project. The EIR allows the Board to make an informed choice while balancing the impact of port development on the environment and the financial benefits of the project to the City of Los Angeles.

When there is federal involvement in port development projects through funding or permits, the port must also comply with the National Environmental Policy Act (NEPA). NEPA is similar to CEQA, as it requires analysis of the environmental impacts of a project prior to federal action on the project. Therefore, CEQ and the California government have made an agreement that a joint EIR/EIS would be applied if certain projects were under the jurisdiction of both CEQA and NEPA. One example would be a port funded both by federal and state governments.

5.1.2 POLICY DEVELOPMENT

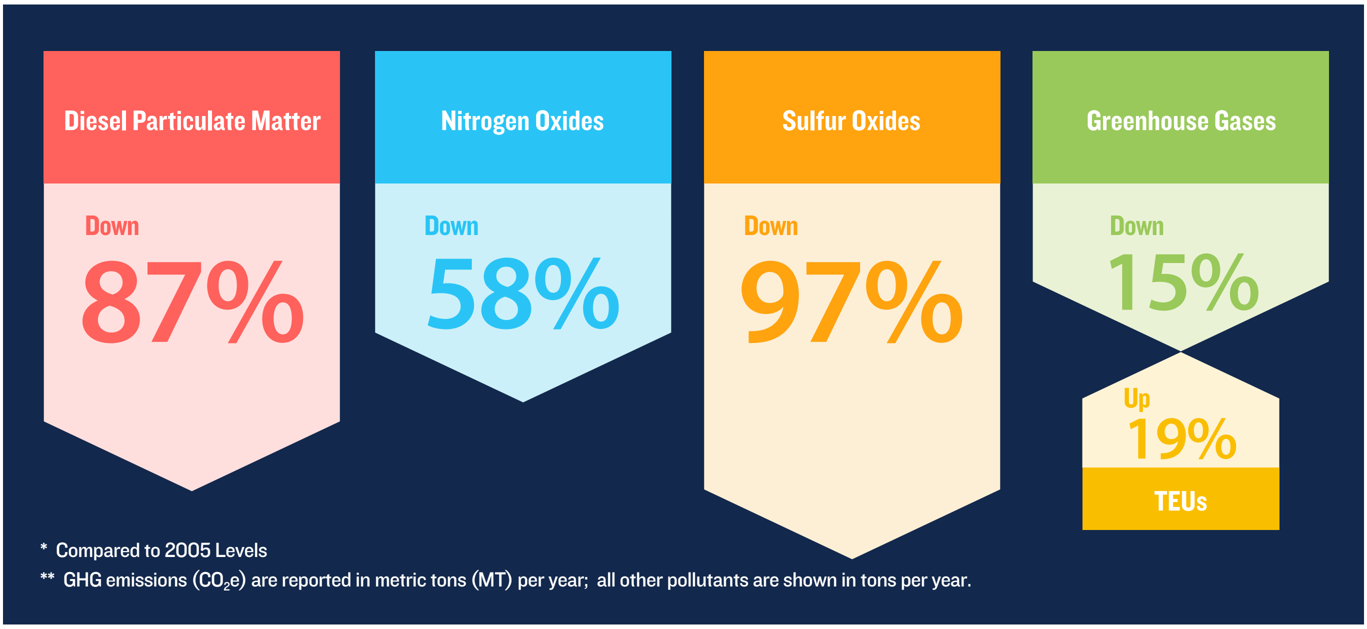
California's environmental regulatory priorities and actions are driven by an array of public concerns. Air pollution control regulations are driven by the broadly held public views that air pollution levels in California can cause extensive, long-term human health problems.

POLA and POLB have seen considerable pressure to increase their attention to environmental issues during the last two decades. A number of factors have been influential:

- In 2006, the California Air Resources Board (CARB) conducted a health risk assessment with exposure to diesel particulate matter (DPM) from emissions generated by the two San Pedro Bay Ports. This study found that the two ports were elevating cancer risk over hundreds of square miles, affecting almost 2 million people, increasing cancer risk by as much as 500 in a million for residents living close to the ports, and causing from 14 to 43 premature deaths each year.[50] The CARB health risk assessment raised public awareness of the amount of emission of air pollutants and impacts on the region ;
- Increased pressure from regulatory agencies like the South Coast Air Quality Management District to reduce emissions in support of the Air Quality Management Plan (AQMP);
- Increased public concern in surrounding communities about port expansions and their impacts on noise, traffic congestion, air pollution, and environmental justice;
- Several major lawsuits that resulted in agreements to mitigate the environmental impacts of the ports on neighboring communities. The lawsuits were major milestones for the relationship among the cities, local communities and the ports. The lawsuits were based on allegations that the ports had failed to comply fully with provisions of NEPA and the more stringent CEQA. CEQA requires that lead agencies, in this case, the two ports, disclose all environmental impacts and, to the extent feasible, mitigate those impacts. As a result of settlements stemming from the lawsuits, the ports, particularly the POLA committed to extensive mitigation of the impacts of port expansion. The lawsuits resulted in delays of several major port expansion projects. These mitigation practices and commitments have become normal operating procedures for the two ports.
- Concerns raised elsewhere in California about the impacts of the freight movement through their communities. In 2006, the State of California produced a Goods Movement Action Plan (GMAP), outlining a comprehensive strategy to address the economic and environmental issues associated with moving goods via the state's highways, railways, and ports. It set goals for improving the flow of goods throughout California. The GMAP identified approximately 200 actions and projects recommended for further investigation, review or implementation. Environmental improvement was a major element of the GMAP. Opportunities provided by the GMAP and funding from the State of California and the U.S. Federal Government have made infrastructure improvements needed to reduce environmental impacts possible.

As the various pressures mounted, the two ports decided to take the initiative to adjust their policies and develop the Clean Air Action Plan and other initiatives to positively respond rather than resist the regulatory pressures. The result became what is arguably the most advanced and aggressive set of environmental initiatives of any port complex in the U.S.

FIGURE 7. 2017 AIR EMISSIONS REDUCTIONS IN SAN PEDRO BAY PORT AREA



5.1.3 CONNECTION WITH THE CLEAN AIR ACTION PLAN OF SAN PEDRO BAY PORTS

The San Pedro Bay Ports Clean Air Action Plan (CAAP), a collaboration of the Port of Los Angeles and the Port of Long Beach, is an air quality plan that established a strategy for reducing port-related air pollution and related health risks while allowing port development, job creation and economic activities associated with that development to continue. The plan proposed strategies to combat air pollution, including the Clean Truck Program, vessel pollution reduction programs, and advanced new technology, such as the world's first hybrid tugboat. The plan was originally adopted in 2006, with updates in 2010 and 2017. With CAAP and other air quality control initiatives, air emissions of these two port areas have decreased significantly compared with the 2005 levels, as shown in Figure 7.

5.1.4 PORT AIR QUALITY CONTROL PROGRAM PLANNING

- Air Emissions Inventory

The POLA and POLB emissions inventories are updated annually and were recognized as the most comprehensive emissions inventories, as they have had to meet the most rigorous drivers for any ports worldwide. The POLA and POLB's annual activity-based emissions inventories serve as the primary tool to track the port's efforts to reduce air emissions from goods movement-related sources through implementation of measures identified in the San Pedro Bay Ports Clean Air Action Plan (CAAP) and regulations promulgated at the state and federal levels. To quantify the annual air emissions, the port relies on operational information provided by port tenants and operators. The development of the annual air emissions estimates is coordinated by a technical working group (TWG), which is comprised of representatives from the Port of Los Angeles, the Port of Long Beach, and the air regulatory agencies: the U.S. EPA , EPA Region 9, the California Air Resources Board (CARB), and the South Coast Air Quality Management District (SCAQMD). Through collaboration with the TWG, the ports seek the consensus of the air regulatory agencies regarding the methodologies and information used to develop the emissions estimates. The regulatory agencies have agreed to include the resulting emissions inventories as their emissions inventories for port-related sources in the South Coast Air Basin, replacing the agency-developed inventories for the two ports.

The POLA and POLB have incorporated the broad South Coast Air Basin air quality modeling geographic domain for their

FIGURE 8. GEOGRAPHIC DOMAIN FOR THE PORT OF LOS ANGELES EMISSIONS INVENTORY

emissions inventories, as intended to be used by both ports and the regulatory communities to develop port-related emissions control policies and track progress. The overwater geographical domain extends over 130 nautical miles (nm) out to sea and is bounded by the basin's land borders to the north and south. The overland geographical domain includes outer boundaries for four adjacent counties. All direct port-related cargo operations are included as the operational domain within the geographic domain. The geographic domain covers a region with a population of over 10 million people (Figure 8).

Emissions are evaluated from the goods movement-related emissions source categories, including ocean-going vessels (OGV), harbor craft, cargo handling equipment (CHE), rail locomotives, and heavy-duty vehicles (HDV).

Exhaust emissions pollutants, including PM_{10} and $PM_{2.5}$, diesel particulate matter (DPM), NO_x, SO_x, HC, CO, and a normalized sum of three greenhouse gases CO_2e,[v] are quantified in the inventory.

The Port of Los Angeles and the Port of Long Beach have conducted the most extensive emissions forecasts of any port. These emissions forecasts were undertaken as part of the San Pedro Bay Ports Clean Air Action Plan (CAAP) and its several updates. These forecasts include cargo growth rates by cargo type,

[v] CO_2e is a normalized sum of three greenhouse gases (GHGs) emitted from maritime industry-related mobile sources: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

future containership call- and size-distributions, the incorporation of all international, national and state regulations, and numerous scenarios related to emissions reduction strategies as part of the CAAP. Figure 9 is from the 2018 POLA Air Emissions Inventory and presents the 2018 and 2005 emissions comparison by five ports-related source categories: ocean-going vessels (OGVs), harbor craft, cargo handling equipment (CHE), locomotives, and heavy-duty vehicles (HDV). Reductions were seen in all pollutants when comparing 2018 to 2005, except for CO emissions for harbor craft and CO_2e emissions for CHE. These reductions occurred even with a 25 percent increase in TEU throughput in 2018 as compared to 2005.

FIGURE 9. POLA 2018 2005 AIR EMISSIONS COMPARISON BY SOURCE CATEGORY[51]

	PM_{10} tons	$PM_{2.5}$ tons	DPM tons	NO_X tons	SO_X tons	CO tons	HC tons	CO_2e tonnes
2018								
Ocean-going vessels	57	53	43	2909	110	250	119	205,486
Harbor craft	27	25	27	813	1	581	89	66,092
Cargo handling equipment	8	7	6	464	2	877	86	188,894
Locomotives	33	31	33	886	1	216	51	76,073
Heavy-duty vehicles	9	9	9	1,482	3	209	34	397,027
Total	134	125	118	6,554	118	2,132	380	933,572
2005								
Ocean-going vessels	534	429	466	5,295	4,825	470	213	288,251
Harbor craft	55	51	55	1,318	6	364	87	56,925
Cargo handling equipment	54	50	53	1,573	9	822	92	134,621
Locomotives	57	53	57	1,712	98	237	89	82,201
Heavy-duty vehicles	248	238	248	6,307	45	1,865	368	474,877
Total	948	820	879	16,206	4,983	3,757	850	1,036,876
Change between 2005 and 2018 (percent)								
Ocean-going vessels	-89%	-88%	-91%	-45%	-98%	-47%	-44%	-29%
Harbor craft	-51%	-51%	-51%	-38%	-88%	60%	2%	16%
Cargo handling equipment	-86%	-86%	-89%	-71%	-78%	7%	-7%	40%
Locomotives	-42%	-41%	-42%	-48%	-99%	-9%	-42%	-7%
Heavy-duty vehicles	-96%	-96%	-96%	-77%	-91%	-89%	-91%	-16%
Total	-86%	-85%	-87%	-60%	-98%	-43%	-55%	-10%

■ Clean Air Action Plan (CAAP) Strategies

At the end of 2017, the Ports of Los Angeles and Long Beach released the final CAAP 2017 Update. The CAAP 2017 Update contains new strategies from all sources that move cargo through the ports, including the deployment of zero and near-zero emission trucks and cargo handling equipment, and the expansion of programs that reduce ship emissions. The focus of the update is to work in collaboration with industry stakeholders, regulatory agencies, local communities, and environmental groups for the next 20 years to reduce emissions and combat climate change. The CAAP 2017 strategies that will affect future emission reductions for both ports include:

- Advancing the Clean Trucks Program to phase out older trucks and transition to near zero emissions in the early years and zero-emissions by 2035 with a truck rate to take effect in 2020.
- Requiring terminal operators to purchase zero-emissions equipment if feasible, or near-zero or cleanest available when procuring new equipment.
- Further reducing emissions from ships at-berth, and transitioning the oldest, most polluting ships out of the San Pedro Bay fleet.
- Accelerating the deployment of cleaner engines and operational strategies to reduce harbor craft emissions.
- Expanding the use of on-dock rail to shift more cargo leaving the port to go by rail.

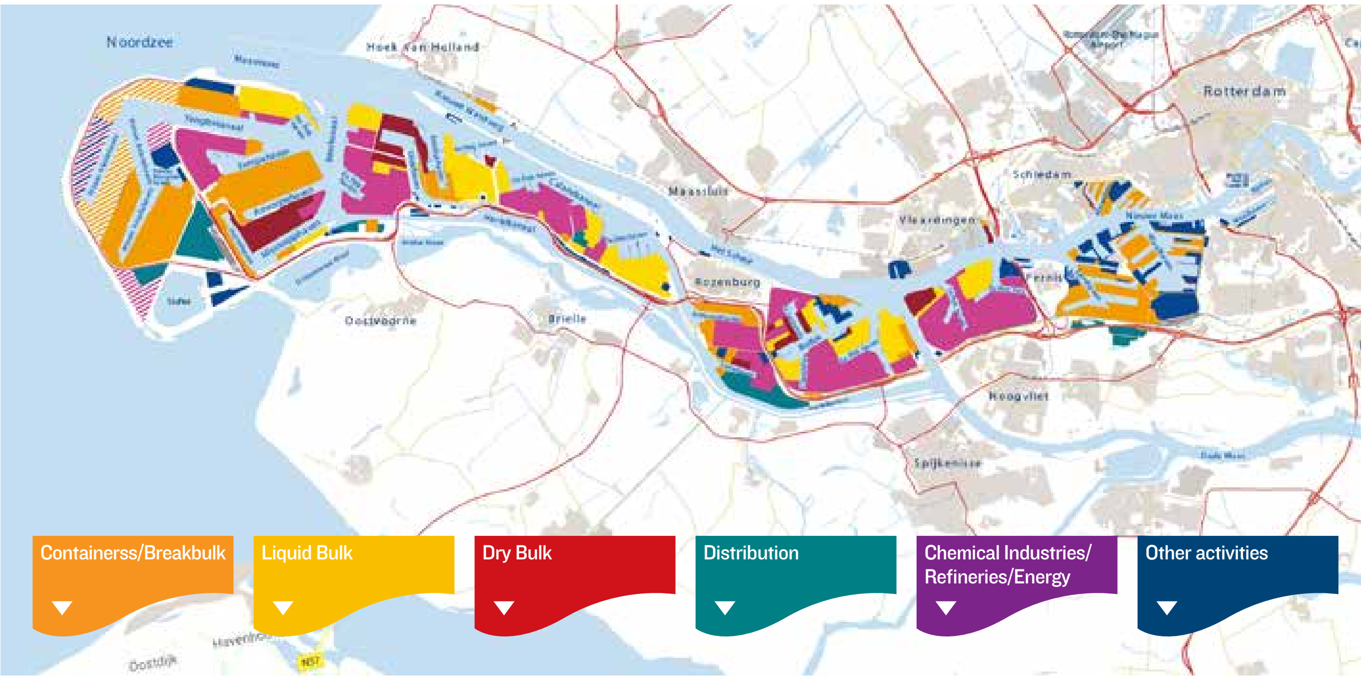
■ Air Quality Monitoring

Since 2005, the Port of Long Beach and the Port of Los Angeles each operate an air quality monitoring network which collect continuous data on ambient air quality and meteorological conditions in the San Pedro Bay region. This air quality monitoring program supports the port's commitment to improve air quality within the San Pedro Bay Ports area by helping to better manage and provide feedback on the port's air quality improvement efforts.

The monitoring stations are strategically located throughout the Ports. The monitoring program includes a network of six air monitoring stations (two within the Port of Long Beach and four

FIGURE 10. SAN PEDRO BAY PORTS' AIR MONITORING STATIONS [53]

FIGURE 11. PORT OF ROTTERDAM AND LOCATION OF MAASVLAKTE 2 [54]



within the Port of Los Angeles) that measure a comprehensive set of air pollutants within the region of influence. The air quality monitoring stations measure ambient air pollution levels in the vicinity of the Ports area. The program includes a number of real-time air quality measurements: ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, two sizes of particulate matter (PM_{10} or coarse particles, and $PM_{2.5}$ or fine particles), polycyclic aromatic hydrocarbons (PAHs), and ultrafine particles. In addition, 24-hour integrated samples of particulates are collected on filters every third day for detailed chemical analyses, which cannot be done with real-time monitors. The real-time environmental data collected by these stations is available for public review online.[52]

As part of the program, meteorological monitoring stations operate adjacent to each air monitoring station to help interpret the air quality data and for use in other port programs. Each meteorological monitoring station collects wind speed, wind direction, and temperature data, while one designated station also collects solar radiation, relative humidity, and barometric pressure data.

Selection of the locations for the two community stations was dependent on a special "validation study,"which ensured that the monitoring sites were representative of ambient conditions within the community.

5.2 CASE STUDY OF THE PORT OF ROTTERDAM

Once the busiest port in the world, the Port of Rotterdam (POR) remains the busiest port in Europe. Covering more than 41 square miles, POR stretches over a distance of approximately 27 miles across the entire waterfront, from Rotterdam city center's historic harbor area to the recently reclaimed Maasvlakte 2 area. Maasvlakte 2 was a major land reclamation that has been extended from the port out into the North Sea.

Petrochemical and chemical industries, as well as general cargo transshipment handling, are key to the port's industrial activities. The harbor functions as an important transit hub for transportation of cargo between the European continent and other parts of the world, with a focus on bulk and tankers (dry and liquid), although the share of containers at POR is gradually increasing. Depending on the quay, POR has a draft up to 24 meters (78 feet), making it one of the few ports, which globally can receive the largest bulk cargo ships in the world when fully loaded. To and from POR, goods are transported by ocean-going vessels, river barges, trains, or via roads.[55]

A comparison of shipping emissions (2004 data) and industry emissions (2007 data) at POR shows that the majority of emissions at the port are attributable to industrial sources rather than shipping.

TABLE 8. AIR POLLUTANT EMISSIONS IN THE PORT OF ROTTERDAM AREA (1000 TONNES)

	MARITIME			INDUSTRY
	SAILING	MANEUVERING	BERTHING	
NO_X	1	4	4	17
Fine Particulates (Combustion)	0.1	0.2	0.3	0.2
SO_2	0.6	3	2	31

Source: Environmental Impacts of International Shipping: the Role of Ports, OECD, 2011

Although the secondary industry is POR's largest source of air emissions, the contribution of sea and inland shipping in the Rijnmond region (Rotterdam and surrounding region) can be significant at certain hotspots. According to a 2004 study, the relative contribution of shipping to total NO_x emissions in the region was estimated to be around 13-25%, while the contribution of PM_{10} to the total concentration was more limited, 10-15% at maximum, with a roughly equal division of the share between ocean-going vessels and inland barges.[56]

Since the mid-2000s, however, POR has initiated a number of mandatory and voluntary programs to reduce air pollution from its own vessel fleet, as well as ships and barges docking at its ports. It has also launched a comprehensive program to reduce climate and air pollution impacts of the port's operation through improved efficiency of the logistic chains and the provision of alternative energy sources. Together with the tightening of permissible sulfur emission levels in fuel in the North Sea ECA zone, the contribution of shipping and port-related goods handling and transporting to air emissions in the Rijnmond region has been further reduced.

In order to strengthen the status of Rotterdam as an important port in Europe and also to adapt the development trend of large-scale and professional intercontinental ocean-going vessels, the Rotterdam authorities decided to build the Maasvlakte 2(MV2) project. The new poet area is located above the North Sea and expands the port land through reclamation. The construction of the Maasvlakte 2, carried out in cooperation between the Dutch government and the Rotterdam city government. The MV2 has been under construction since 2008 and the first phase has been put into use in 2013. The water depth of the port area is 19 meters, which can meet the call of 12000 TEUs container ships, and can accommodate a maximum annual throughput of 4.5 million TEUs (standard container size). The area will provide room for container transshipment (600ha), chemical industry (300ha) and distribution activities (100 ha).

The construction of Maasvlakte 2 takes environmental factors into account to a great extent and the measures of sustainable development are clearly put forward. A comprehensive EIA study was conducted for Maasvlakte 2, including a separate 380-page appendix on air quality, assessing the air quality impacts in compliance with the Decision Air Quality 2005, which implemented the European EIA Directive and anchored it in Dutch national legislation. Assessments were conducted for NO_x, SO_2, and PM_{10}. $PM_{2.5}$ was not considered due to a lack of information on present and future anticipated background levels in the region. For the purpose of the EIA, three project development alternatives were being considered, across different industrial development scenarios and with a timescale up to 2020 (partial operation of Maasvlakte 2) and 2033 (full operation of Maasvlakte 2). The alternatives included a master plan alternative, the most environmentally friendly alternative including some measures beyond the direct remit of the POR, and a preferred alternative, which included environmental measures that the consulted stakeholders were willing to implement / guarantee were developed.[57]

For the purposes of the air quality impact assessment of Maasvlakte 2, the area that had to be considered was defined as the direct surroundings of the Maasvlakte 2, including nearby residential areas, as well as important transportation corridors inland up to about 40km from the Maasvlakte 2. In addition, if any significant changes in traffic intensities, traffic congestion, and hotspots for (nautical) safety were to occur outside the mentioned study area, these would have to be assessed as well. Emissions were calculated for a likely development path and for a worst-case scenario, followed by an assessment of air quality bottlenecks and a sensitivity analysis using the "New National Model". The New National Model is a Dutch model for air quality emissions modeling, for which two software packages, called Pluimplus and Stacks, are available in the Dutch market.

The following figure shows the anticipated total NO_2 emission levels in the Rijnmond region (Maasvlakte 2 is located on the far left side) in 2033 under a fully operational Maasvlakte 2.

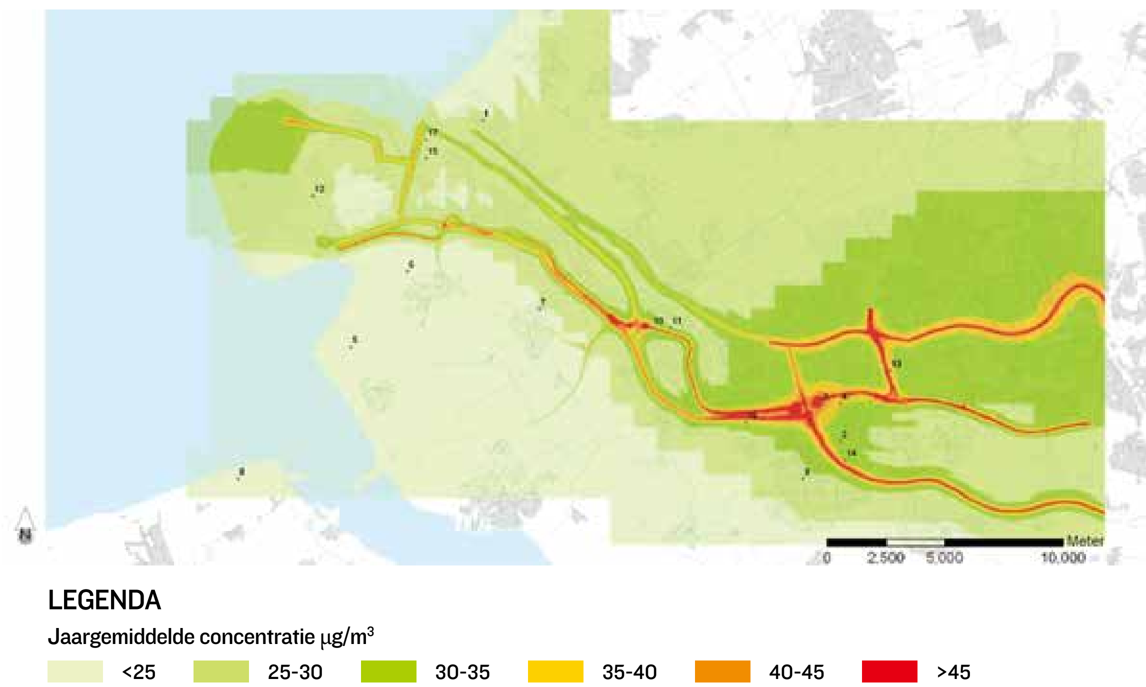
Calculations for the air quality impact of Maavlakte 2 showed that EU air quality standards would not always be met everywhere in the so-called Rijnmond area with Maasvlakte 2 in operation. The 24-hour standard for PM_{10} and the annual average NO_x concentration would be exceeded along certain maritime fairways, near several highway tunnels and in the town of Hoek van Holland, which is located near the POR harbor entrance.

After consulting with experts, a package of measures for reducing air emissions at hotspots was selected and assessed against their technical, legal and economic feasibility. The reduction in air emissions impact was calculated for the various alternatives considered for 2020 and 2033 to determine which measures to be taken forward. Additionally, recommendations for monitoring measures and locations were also included in the EIA.

One of the measures put in place stemming from the adverse impacts predicted by air quality modeling in the EIA of Maasvlakte 2 was the creation of an 'environmental zone', implemented by the Rotterdam municipality in the port area in 2013. This zone is expected to improve local air quality and compensate for increased road-based traffic in Maasvlakte 2. From 2013 onwards, trucks that do not meet the EU Euro V-standard have been banned from the Maasvlakte 1 (the previous expansion) and the Maasvlakte 2 area. Since 2016, the measure has been upgraded to require trucks to meet the Euro VI standard. The EIA process also led to POR strongly supporting the EU's designation of the North Sea and the Baltic Sea as Nitrogen Emission Control Areas (NECA) in 2021. International studies have shown that the designation of a NECA is a cost-effective way to reduce NO_x emissions from seagoing vessels.

The POR has developed extensive Monitoring and Evaluation Programs for the entire lifecycle of Maasvlakte 2, with the outcomes reported to relevant Dutch authorities as well as to the European Commission to the extent appropriate. A monitoring plan lays out how impacts are to be monitored and who is responsible for doing so. In addition, progress reports (Maasvlakte 2 Monitor) have so far been published in 2010, 2012 and 2014 and were publicly available on the Maasvlakte 2 website.[59]

FIGURE 12. RIJNMOND REGION 2033 NO_2 EMISSION LEVEL [58]



6

LESSONS LEARNED AND RECOMMENDATIONS

The scope of the EIA analysis must include ALL environmental impacts so as to have a full appreciation of what those impacts are. In the context of ports, the direct, indirect, and cumulative impacts of port planning, construction, and operation must be analyzed. International experiences indicate that port-related mobile source pollution from vessels, port equipment, cargo trucks, and locomotives must be integrated into and properly assessed in the EIA. Mobile source emissions have received more and more attention in the port EIA process of China. However, from the perspective of international experience, further improvement is needed. Drawing on lessons learned from the U.S. and EU case studies, some recommendations on improving EIA for ports tailored to China's context are summarized as follows.

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6.1 STRENGTHEN THE SCIENTIFIC BASIS OF PORT EIAs

6.1.1 ACTIVELY IMPLEMENT ATMOSPHERIC ENVIRONMENT MONITORING IN PORT AREAS

Long-time, continuous and full-factor atmospheric environmental monitoring data and corresponding meteorological and climatic observation data are the basis for effectively incorporating atmospheric environmental assessment into port EIAs. To this end, the Port of Los Angeles has four observation stations in the port area, and the Port of Rotterdam has also carried out long-time atmospheric environmental monitoring. For a long time, the atmospheric environmental monitoring stations and data in China's port areas are seriously inadequate. Most of the ports can only rely on the monitoring stations and data of their cities. Due to the special characteristic of the port air emission, the pertinence of the citywide data is insufficient to reflect the actual amount in the port area. With the implementation of the pollution discharge permit regulation, ports began to plan and build independent air monitoring stations, and this situation will gradually change. Therefore, it is necessary to actively monitor the atmospheric environment of the port regional system. The monitoring indicators should take into account not only general indicators such as particulate matters, sulfur dioxide, and nitrogen oxides, but also characteristic factors of port emissions, such as carbon monoxide, volatile organic compounds, and black carbon.

6.1.2 CONSTRUCT A COMPREHENSIVE AND REGULARLY UPDATED INVENTORY OF ATMOSPHERIC EMISSION SOURCES IN PORT AREAS

The atmospheric pollution emissions in port areas come from land and sea, including both stationary and mobile sources. Therefore, to construct a complete and dynamically updating list of atmospheric emission sources is the prerequisite of developing an effective EIA for ports. At present, China is about to complete the second national pollution source census, including the regional stationary atmospheric emissions sources surrounding port areas. A complete list of atmospheric emissions sources can be developed by incorporating all kinds of mobile sources and stationary sources. In addition, considering the variability of mobile sources, the periodically updating or reviewing (every three to five years or as warranted by activities levels) of emissions source inventory should be incorporated into the EIA uncertainty analysis.

6.2 IMPROVE THE SCIENTIFIC NATURE OF PORT EIA ANALYSIS

6.2.1. Develop a Comprehensive Port Air Pollution Model

The port is a composite area containing land and sea. The experience of the Port of Rotterdam shows that the development of a model for port air pollution simulation will greatly enhance the scientific nature of port EIA analysis. The port area is affected by the interaction of sea and land atmospheres, as well as the surface of the basement of the land, coast and offshore. Therefore, it is necessary to consider the matters mentioned above in the development of the port air pollution model. A scientific and effective air pollution model will provide a powerful tool for EIA analysis and prediction, as well as for assessing the effectiveness of air pollution control measures.

6.2.2 ASSESS MOBILE SOURCE EMISSIONS DURING PORT OPERATIONS

International experience shows that it is important to project emissions for the expected life of a port project. A port planning EIA should not only cover construction stage air pollution but also pay more attention to air pollution from mobile sources (ships, trucks, port equipment and railway) during future port operations. The CEQA process, as well as the Port of Los Angeles and Port of Long Beach experiences, indicate that requiring ports to project the air pollution level after the proposed expansion and allowing for oversight by the public can compel the port authority to initiate control measures that could offset the projected growth in air emissions due to port expansion.

6.3 EXPAND THE SCOPE OF PORT EIAS

6.3.1 PROMOTE CO-CONTROL OF AIR POLLUTION AND GREENHOUSE GASES

As the international community attaches more importance to climate change issues, initiatives to jointly control air pollution and greenhouse gases are increasingly being explored. Some countries have begun to incorporate greenhouse gases into

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their EIAs. With the completion of institutional reforms, China has integrated air pollution and greenhouse gas management into the same department, providing a good opportunity and mechanism for the coordinated control of air pollution and greenhouse gases. For the port EIA, the interrelated "cars, boats, machinery, oil, coal, and gas" provide a practical platform for the coordinated control of atmospheric pollution and greenhouse gases, and are also the objects that must be considered in the atmospheric environmental management of the port.

6.3.2 SELECT A REASONABLE GEOGRAPHICAL DOMAIN

In general, a port-related mobile source assessment should cover all source sectors and geographical areas of interest. This typically includes, at a minimum, the geographical area within the port authority or other port operator's jurisdiction. It frequently also includes port-related traffic in nearby transportation corridors. The assessment should cover an entire port, including marine boundaries and landside boundaries where the port-related vessel and freight activities occur.

6.4 STRENGTHEN THE EFFECTIVENESS AND WHOLE PROCESS MANAGEMENT OF PORT EIAS

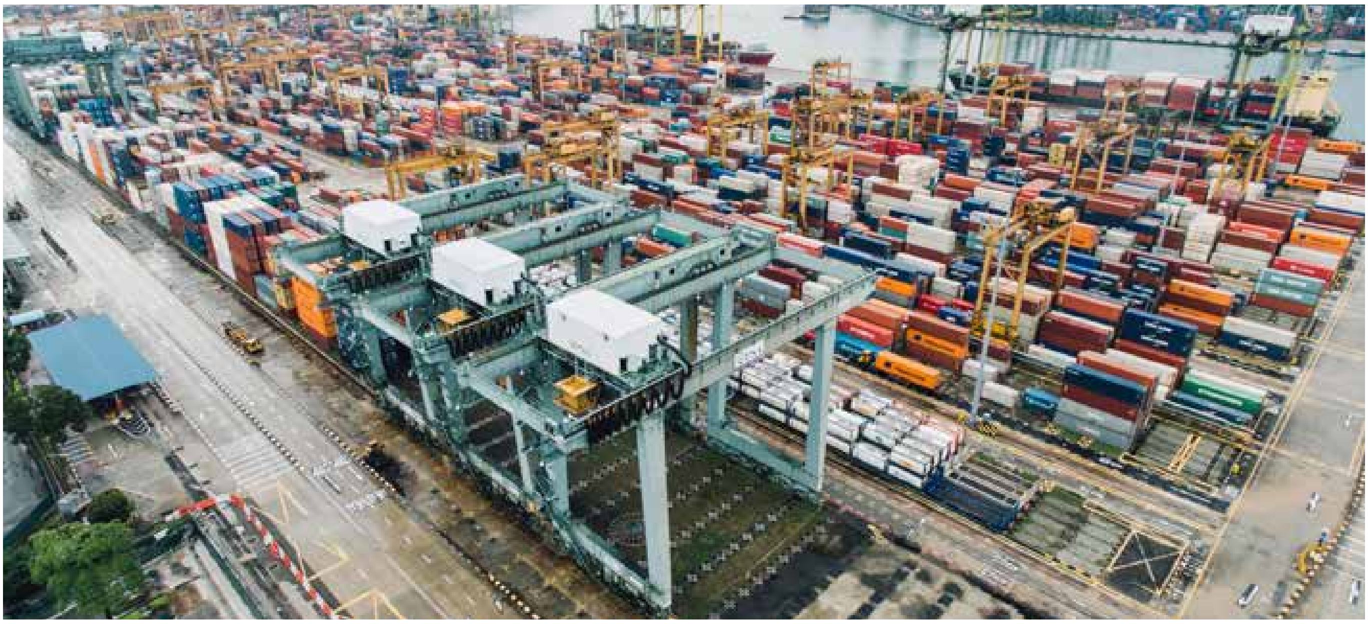
6.4.1 CARRY OUT PORT AIR POLLUTION CONTROL ACTIONS AND STRENGTHEN POST-EIA SUPERVISION

Incorporating atmospheric environmental assessments into the port EIA is only the first step in the port's atmospheric environmental management. The more important function of the port EIA is to drive the whole environmental management process, that is, to develop specific, targeted, and operable air pollution control measures for the port and to implement them. Air pollution control measures must be reviewed and updated in accordance with port development and environmental protection requirements. The port air pollution control action is not only a follow-up to the EIA, but also an environmental guide for port construction and operation. In general, port air pollution control actions should include monitoring, data collection, collation and analysis, simulation and implementation assessment. Specific measures, such as dust management, oil quality standards, delimitation of coal-free zones or forbidden oil zones, shore power, and capacity building, have all started to be implemented in various port areas. The follow-up assessment is important to evaluate the effectiveness of these measures in reducing emissions.

6.4.2 STRENGTHEN THE DEPARTMENTAL COORDINATION AND IMPROVE THE PUBLIC PARTICIPATION

The experiences of the Port of Los Angeles and the Port of Rotterdam show that port environmental impact assessment and air pollution control involve coordination among multi-level government departments and related institutions in various fields, as well as participation by non-governmental organizations (NGOs) and surrounding communities. Therefore, establishing a mechanism by which all relevant departments can participate and provide the public with adequate channels for environmental information disclosure and participation is an effective measure to strengthen the effectiveness of port EIAs and improve the environmental responsibility of the competent authorities.

The same is true for China's port environmental management, which involves not only various government departments but also enterprises, social groups and the public. In general, relevant government departments should adopt effective mechanisms and measures to improve the unification of policies and standards and provide uniform standards and requirements for the implementing entities. It's necessary to encourage and summon more enterprises, social organizations and the general public to participate in the management of EIA, and to play active and aggressive roles on social supervision of port air pollution management actions.



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List of Abbreviations

BC	Black Carbon
CAAP	Clean Air Action Plan
CARB	California Air Resources Board
CEQA	California Environmental Quality Act ()
CH_4	Methane
CHE	Cargo Handling Equipment
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DECA	Domestic Emission Control Area
DPM	Diesel Particulate Matter
ECA	Emission Control Area
EMFAC	Emissions Model for On-Road Vehicles (CARB)
EIA	Environmental Impact Assessment
EU	European Union
FYP	Five Year Plan
GHG	Greenhouse Gases
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
MEE	Ministry of Ecology and Environment
MOT	Ministry of Transport
MOVES	Motor Vehicle Emissions Simulator (U.S. EPA)
N_2O	Nitrous Oxide
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
NO_x	Nitrogen Oxides
NPSA	Nation Port Strategy Assessment (U.S. EPA)
OPS	Onshore Power Supply
OGV	Ocean Going Vessel
PM	Particulate Matter
POLA	Port of Los Angeles
POLB	Port of Long Beach
POR	Port of Rotterdam
RTG	Rubber-Tired Gantry Crane
SCR	Selective Catalytic Reduction
SO_2	Sulphur Dioxide
SEA	Strategic Environmental Assessment
TKP	Technical Key Points of Environmental Impact Assessment for the Port Master Plan
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds

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