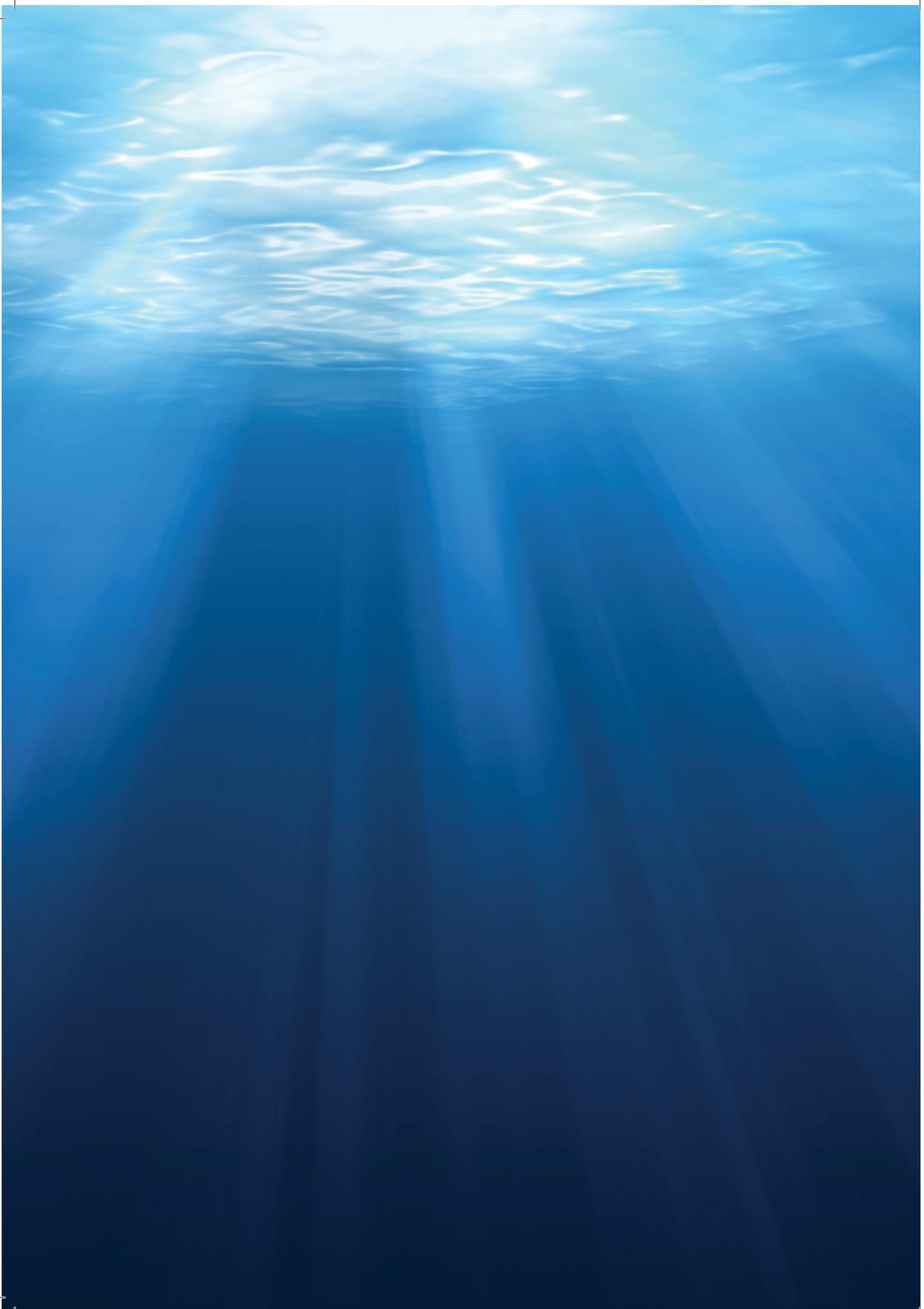




ENABLING CLEAN MARINE TRANSPORT

MARCH 2017

**PREPARED FOR THE G20
ENERGY SUSTAINABILITY WORKING GROUP**



LNG as a Path to Enabling Clean Marine Transport

Liquefied Natural Gas, or LNG as marine fuel offers substantial advantages over traditional marine petroleum fuels in emissions reduction. It meets the stricter pollution regulations by the International Maritime Organisation (IMO) and regional air quality controls. Using LNG will reduce harmful air pollutants significantly below all current and proposed emissions standards. A switch to liquefied natural gas will immediately result in these reductions and persist for the life of the vessel.

Clear, consistent, and efficient regulatory frameworks are an essential requirement for the deployment of any new technology. In the case of marine LNG fuel transition, it is particularly pertinent, since the marine sector is subject to a complex regulatory environment with overlapping jurisdictions that range from local to global.² When lines between diverse regulatory bodies blur, it often leads to significant barriers for industry.³ This situation is a key barrier facing LNG marine deployment globally and government must be encouraged to set clear regulatory guidelines that are essential in achieving broader and fleet-wide conversions.

The case for using LNG fuel for shipping is clear, as it will provide significant quality of life improvement by addressing one of today's most pressing environmental challenges – air pollution. It will also support climate change goals by reducing greenhouse gases (GHG's).⁴

This situation is a key barrier facing LNG marine deployment globally, and governments must be encouraged to set clear regulatory guidelines that are essential in achieving broader and fleet-wide conversions.

While marine transportation is the most carbon-efficient mode of transport, in terms of CO₂ emitted per unit of cargo, compared to road, air, or rail, the massive scale of shipping activities generates significant emissions, in absolute terms.⁵ The main pollutants of concern are sulphur dioxide (SO₂), nitrogen oxides (NOx), carbon monoxide (CO), black carbon, particulate matter (PM), and CO₂.

¹ Thomson, et., al., 2015

² DNV-GL, 2014

³ West Coast Marine LNG Joint Industry Project Steering Committee, 2015

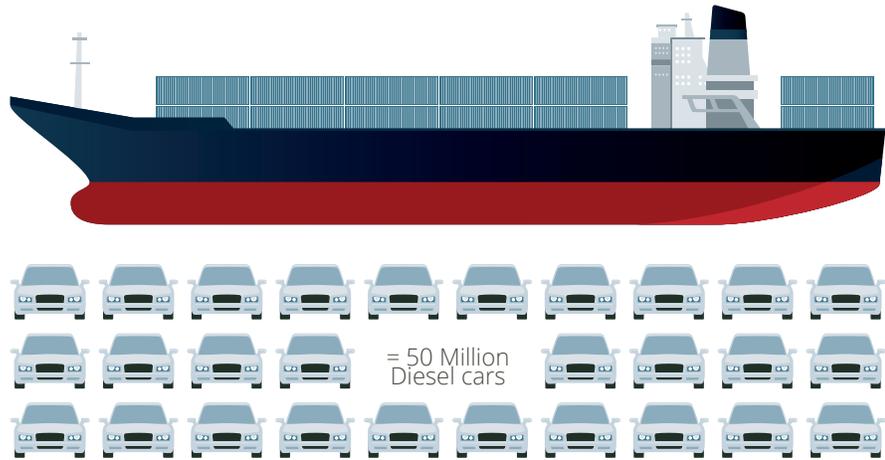
⁴ IMO, 2016

⁵ OECD, 2014

⁶ Fung, et., al., 2014; OECD, 2014

Figure 1

“One large container ship at sea (using 3% bunker fuel) emits the same amount of sulphur oxide gases as 50 million diesel-burning cars.”



Source: China Daily Asia, Ship Emissions Choking the Region, May 20, 2016

Ship emissions have significant human health and environmental costs. The majority (70%) of these emissions occur within 400 km of coastal communities – mainly in the coastal East Asia, South Asia, and Europe. Approximately 230 million people are exposed directly to these harmful emissions in the world’s top 100 ports.⁹

The external costs of NO_x, SO_x, and PM emissions for 50 largest ports in the OECD are almost EUR 12 Billion annually⁸

Examples of Emissions Cost Estimates from Literature

Port	Indicator	Estimate Cost
Bergen (Norway)	Emissions of Ships at Berth	EUR 10-22 million
13 Spanish ports	PM2.5, SO ₂ , NO _x	EUR 206 million
Piraeus (Greece)	External cost per cruise passenger	EUR 2.9-10.4
Kaohsiung (Taipei)	Emissions of Ships at Berth	EUR 119.2 million

Source: OECD, 2014

Strong policy responses are needed, in order to reduce these costs and mitigate the toxic pollution impacts. Global regulations, such as the recently introduced 0.5% sulphur limits by the International Maritime Organisation (IMO), more emission control areas (ECA’s) with stricter limits in coastal areas, or individual port initiatives are all good policy tools to achieve better environmental outcomes for the marine sector.⁹

⁷ MACCII 2014; OECD, 2014

⁸ OECD, 2014

⁹ OECD, 2014

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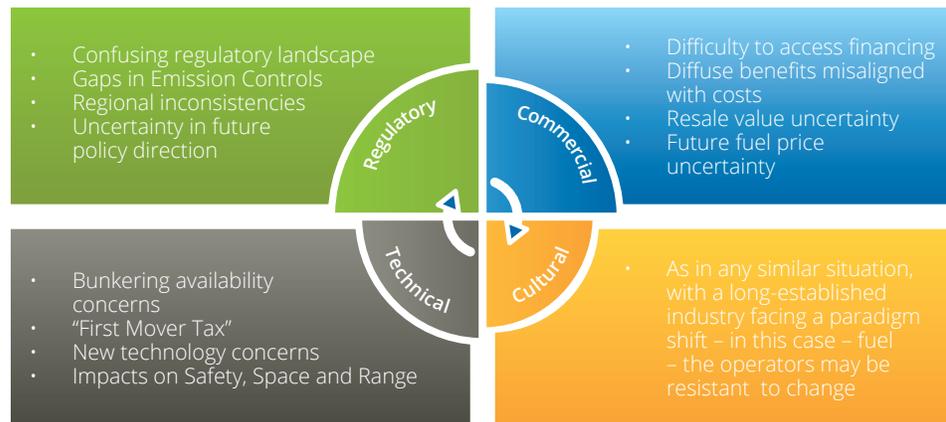
POLICY BRIEFING

Many barriers to the greater deployment of LNG as a marine transportation fuel exist, and their majority will be addressed by the market, as the industry continues to gain experience with the technology and its application.

Governments can assist this process by accelerating technology demonstrations and R&D funding, to improve marine LNG technologies and enhance operational learning.

The areas where policy action would be most valuable are in addressing the regulatory and commercial barriers, which are slowing the development and deployment of cleaner LNG marine technologies, even when the business case is strong.

Barriers Summary



I. RECOMMENDATIONS

Regulatory

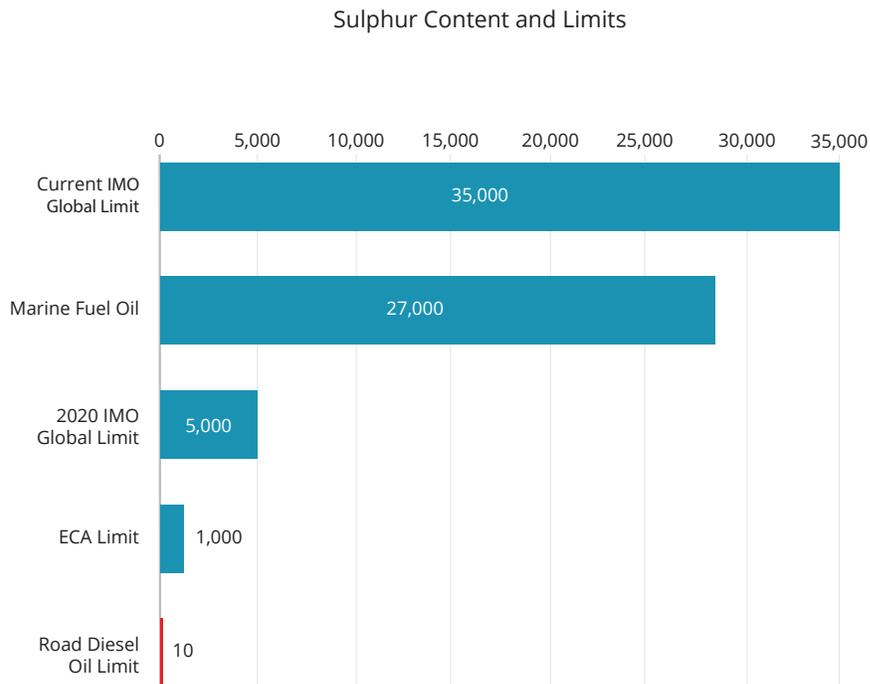
1. Regulate Emissions

The G20 governments should aspire to harmonize marine emissions control regulations. This sector has been significantly lagging behind land transport in emissions control, even though the marine pollution is no less harmful to human health and imposes major economic costs on port cities and surrounding areas.¹⁰ Airborne pollution can travel 10's of kilometres inland,¹¹ and it causes significant health issues in many port cities. In some cases, such as Hong Kong, ship traffic is responsible for half of the city's total toxic pollutants, more than power generation and transportation sectors.¹²

While the developed world is largely moving to strengthen the regulatory regime for controlling marine emissions, developing countries are often lagging – and that is where pollution is costing the most.¹³

The G20 is an ideal vehicle to expedite the harmonization of global emissions regulation, and it should place high priority on this issue because marine emissions are harmful to human health, the environment, and contribute to climate change.

Figure 2



Source: IGU, 2015; IMO, 2016

¹⁰ Fung, F., et., al., 2014; MACCII 2014; IGU, 2015

¹¹ Liu, Z., et., al., 2017

¹² Fung, F., et., al., 2014

¹³ IGU, 2015; Fung, Z., et., al., 2014

2. Identify and Eliminate Gaps

The G20 governments should review their domestic legislative and regulatory frameworks pertaining to LNG marine operations, and identify and eliminate gaps and/or conflicts. Practices from early adopters, such as Norway, can serve as useful guide, as well as, the latest developments in codes and standard guidelines from the IMO, classification societies, and the international community. Regional coordination would be highly useful as well, in that there are already existing inter-jurisdictional initiatives for standards development.¹⁵

Some specific areas of government action that should be prioritized to develop efficient policy frameworks around LNG marine applications are:

- Facilitate domestic standards development, in line with international activity.
- Streamline domestic regulatory processes, ensuring there is a clear lead body responsible. Marine LNG facilities often face higher regulatory costs, due to the lack of clear regulatory and approval processes, which can discourage investment.

Commercial

Facilitate Access to Financing

The initial investments in LNG vessels are more capital-intensive, than the conventional bunker fuelled ships. Difficulty accessing traditional financing, due to the debt issuers' limited experience with the technology is a major barrier,¹⁶ despite the conversions to LNG being a relatively secure investment, with a positive business case and a reasonable payback period.¹⁷

The G20 governments should enable credit financing for marine LNG investments. Several mechanisms are available, and many governments have experience with such mechanisms for supporting alternative energy deployments. These mechanisms generally fall into two categories: governments can either issue credit directly, or act as guarantor for commercial lenders, provided a well-defined set of qualification criteria, with appropriate risk controls are in place.

This recommendation also applies to supporting port bunkering infrastructure development.

Technical

Fund Technology Development and First-mover Deployments

Marine LNG is a commercial technology with a growing deployment rate. However, continuous improvement in LNG engine and ship design will help accelerate economic and environmental performance, further reducing marine emissions.

LNG bunkering is another key area where supporting first-movers is important. This is young industry, and a standardized one-size-fits-all solution does not exist. LNG bunkering can be done in a variety of ways, and each port must assess it on a case-by-case basis, to find the most cost-effective option for its unique operational and technical characteristics.¹⁸ Hence, the first-mover challenge will persist for port bunkering investment for some time.

G20 governments should provide de-risking funding for technology innovation and unique bunkering investments.

¹⁴ West Coast Marine LNG Joint Industry Project Steering Committee, 2015; DNV-GL, 2014

¹⁵ See China, and Japan-Singapore case

¹⁶ e.g. Schinas and Butler, 2016; EC-TNO, 2015

¹⁷ West Coast Marine LNG Joint Industry Project Steering Committee, 2015; DNV-GL, 2014

Summary of Recommendations and Barriers

	Regulatory	Commercial	Technical	Cultural
	<ul style="list-style-type: none"> · Unclear regulatory landscape · Gaps in Emissions Controls · Regional inconsistencies · Future policy uncertainty 	<ul style="list-style-type: none"> · Access to financing · Diffuse benefits · Resale value uncertainty · Fuel price uncertainty 	<ul style="list-style-type: none"> · Bunkering availability · "First Mover" · New Technology · Safety, Space, and Range 	<ul style="list-style-type: none"> · Resistance to change
Regulate Pollution	✓	✓		✓
Identify and Eliminate Gaps	✓	✓	✓	✓
Facilitate Access to Financing		✓	✓	✓
Fund Technology Development and First-mover Deployments		✓	✓	✓

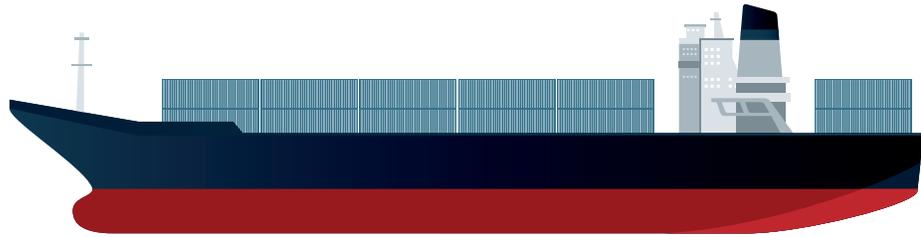
II. DRIVERS

There are several powerful drivers for robust policies to enable the deployment of LNG as a marine transportation fuel. Some jurisdictions, such as Europe and the US, have recognized them and moved to begin developing policy frameworks in support of LNG fleet deployment.¹⁸ However, more work remains to be undertaken globally to unlock the immediate and significant environmental, social, and economic benefits of transitioning to LNG marine fuel.

The policy drivers, or the value proposition of LNG transport, can generally be classified into three categories: 1) environmental – delivering significant public benefits by addressing pollution and climate change issues; 2) economic – delivering value to the economy; and 3) social – delivering improvement in public health and extending lives.

¹⁸ IMO, 2014; EC-TNO, 2015

¹⁹ Thomson, et., al., 2015



A medium- to large-size container ship, running at 70% maximum power for one day using bunker fuel with 35,000 ppm (3.5%) sulphur, emits as much PM2.5 as the average of half a million new trucks in China, during that same day.



Source: Fung, Freda, et al. Prevention and Control of Shipping and Port Air Emissions in China. Natural Resources Defense Council White Paper, 2014.

Diesel PM or the soot in diesel exhaust is a carcinogen, designated by the World Health Organisation. These are tiny toxic particles consisting of roughly 40 different toxic air contaminants, 15 of which are carcinogenic. Some of these toxic chemicals can travel as far as 10,000 km via the PM in the air.²⁰

Key Policy Drivers for Enabling LNG Marine Fuel Deployment

Environmental Drivers

Urban air quality & GHG reductions

The use of LNG in marine transport delivers significant reductions in pollution from ship exhaust and GHG emissions. Even compared to cleaner diesel fuels, transition to LNG provides the following reductions:

- SOx of over 90%
- NOx up to 85% for Otto-cycle engines & 35% for diesel-cycle
- CO₂ up to 29%
- GHGs up to 19%
- PM 85%

²⁰ West Coast Marine LNG Joint Industry Project, 2014

Economic Drivers	<p>Boost industry competitiveness, innovation, and economic growth</p> <p>Direct</p> <ul style="list-style-type: none"> • Switching to LNG fuel translates into substantive savings on the cost of fuel to the operators (business case varies by vessel type and operational characteristics) ²¹ • For port jurisdictions, LNG bunkering can provide a lucrative business, and for governments bring value from local infrastructure investments and job creation²² • For jurisdictions that have LNG resources, this unlocks an additional stable market and a revenue stream ²³ <p>Indirect</p> <ul style="list-style-type: none"> • Positive spill-overs from increased LNG vessel deployment, including development of industrial base ²⁴ • For jurisdictions that are home to ship-building industries, there will also be additional benefits from new product development and innovation spillovers ²⁵ • Energy security - for jurisdictions with limited domestic energy resources, LNG provides another flexible and abundant alternative fuel source.²⁶
Social Drivers	<p>The societal benefits from switching to cleaner LNG-fuelled shipping can be viewed as an extension of the economic benefits; however, due to a lack of price mechanisms for pollution and its detrimental impacts on health and mortality, they are characterized differently.</p> <p>Air pollution from shipping contributes in respiratory, pulmonary, and oncological diseases, as well as premature deaths. Although not explicitly priced, these phenomena have real economic costs and negative GDP impacts.²⁷</p>
Energy Security	<p>The abundance, flexibility, and diversity of LNG provides an additional resource towards enhancing energy security.</p>

²¹Schinas and Butler, 2016; West Coast Marine LNG Joint Industry Project Steering Committee, 2014; EC-TNO, 2015.

²²The Steering Committee for LNG Bunkering at the Port of Yokohama, 2016; West Coast Marine LNG Joint Industry Project Steering Committee, 2014

²³West Coast Marine LNG Joint Industry Project Steering Committee

²⁴Ibid

²⁵Ibid

²⁶EC, 2014; EC, 2016; EC-TNO, 2015

²⁷Fung, F., et., al., OECD, 2014; OECD, 2016

III. BARRIERS

There is a wide range of studies demonstrating a very strong business case for LNG-fuelled ships, especially in certain segments of the global fleet.²⁸ However, even when the economics are positive, operators remain hesitant to invest, due to a number of barriers, both real and perceived.²⁹ These barriers span four areas: regulatory, commercial, technical, and cultural.



Regulatory Barriers

• **Confusing regulatory landscape:** there are currently a patchwork of regulatory regimes enforced by different government bodies³⁰ – ranging from international, to national, and sub-national levels. Some jurisdictions lack a regulatory regime for LNG-fuelled ship and bunkering completely, while others may have restrictions in place, effectively banning LNG shipping activities, as an unintended consequence of a legacy regulation – e.g. classifying LNG as a hazardous substance.³¹

LNG marine fuel is a fairly new application, and ensuring that there are clear domestic policy frameworks and regulations for LNG shipping, bunkering, and related infrastructure is of vital importance. Convoluted approval processes, or absent guidelines for deployment are a powerful barrier for investment.³²

This is often the case because many jurisdictions still do not have a lot of experience with the marine use of LNG. However, there are also jurisdictions which are quite advanced – the early adopters – that can be used as models. Norwegian regulations for example, comprehensively address ship design, operation, training, and bunkering.³³

²⁸ See for example: Schias & Butler, 2016; IMO, 2016; EC-TNO, 2015; West Coast Marine LNG Joint Industry Project Steering Committee; DNV-GL, 2014

²⁹ Schinas and Butler, 2016.

³⁰ DNV-GL, 2014; West Coast Marine LNG Joint Industry Project Steering Committee, 2014

³¹ EC-TNO, 2015; West Coast Marine LNG Joint Industry Project Steering Committee, 2014

³² Ibid

³³ Ibid

Norway has been at the forefront of marine LNG applications, dating back to 2000. Initially, the Norwegian government only allowed loading of LNG on vessels that did not transport passengers. However, starting in 2014, it permitted bunkering of Fjord Line cruise ships with passengers on board.

In Stockholm, bunkering of Viking Line cruise ships with passengers on board was approved in 2013.

These developments highlight the changing environment of safety regulations and public acceptance of LNG as a viable fuel option.

Viking Line Cruise:



• **Gaps in Emissions Control:** the world's busiest and fastest growing ports are today in the non-OECD world³⁵, where emissions controls are often lagging behind the international standard.³⁶ (see Figures 3 and 4).

Emissions control is a major driver for choosing LNG, and the business case has a strong correlation with the amount of time spent in the ECA³⁷ waters. At the same time, pollution from ports is a major contributor to premature deaths and economic losses for the developing countries, and the international community can help address this issue by harmonizing international emissions regulations.

³⁴ IGU, 2015

³⁵ World Shipping Council; Thompson, 2016.

³⁶ IGU, 2015

³⁷ Emission Control Areas (ECA's) are four designated coastlines where the IMO standards for allowable emissions are much stricter, in order to protect local air quality: North Sea, the Baltic Sea, North America, and US Caribbean.

Figure 3
Evolution of Global Non-Road Emissions Regulations

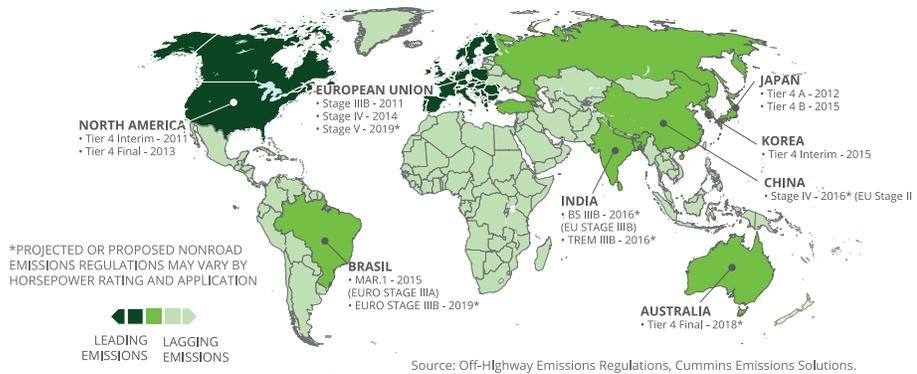
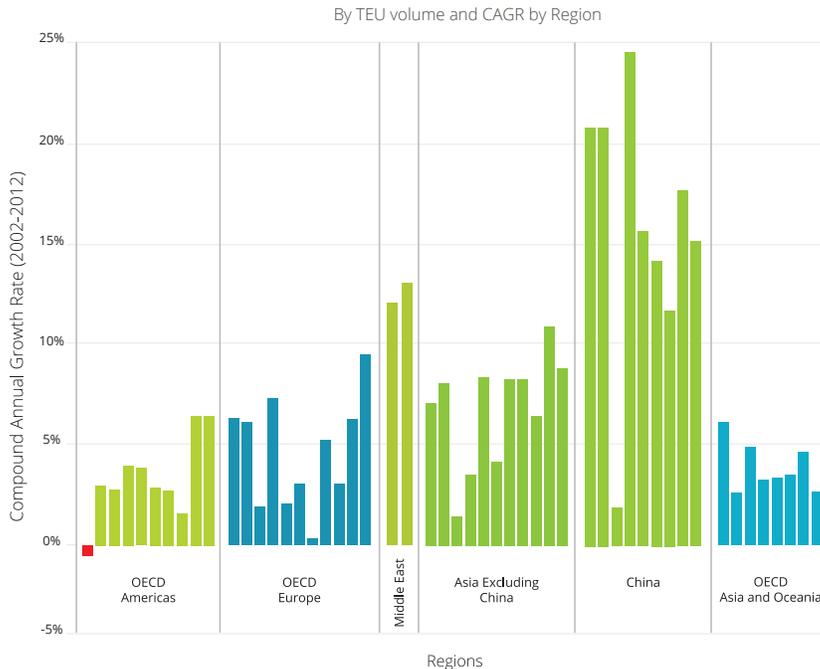


Figure 4
 Growth Trends in Major Global Ports by Region (2002-2012)



Source: Thomson, H., J.J. Corbett, et., al. Natural Gas as a Marine Fuel. Energy Policy (87) 153-176, 2015.

• **Regional inconsistencies:** a lion's share of the marine sector operates internationally, and it is important that regional policy and regulations are consistent and mutually-reinforcing. Furthermore, efforts of pro-active local jurisdictions could be undermined, if their neighbours do not enforce similar regimes. For example, it is the flag states who enforce IMO regulations and also decide what technologies are in compliance³⁸.

• **Future policy direction:** A ship's lifetime is over 25 years, and thus an investment decision on fuel technology conversion has long-term implications for the operators. Investors need to be certain that their assets will not be deemed obsolete, due to a future regulatory change. ³⁹ Governments need to provide clear stable policy to ensure certainty for LNG conversion investments.

³⁸ IMO, 2016.

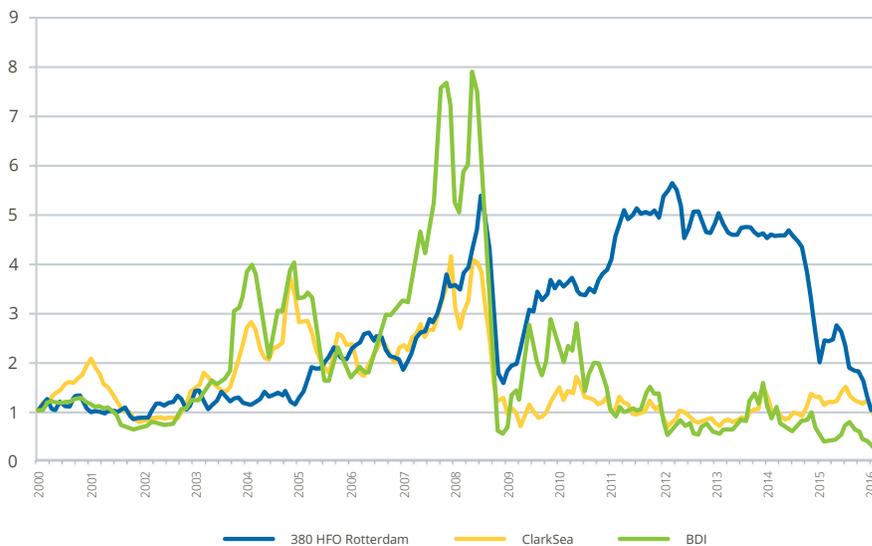
³⁹ DNV-GL, 2014

Commercial Barriers

- **Access to capital:** The traditional ship-building financiers are hesitant to provide investment capital, largely due to the limited experience and uncertainty about the ship resale value.⁴⁰ This is particularly challenging, since the initial investment for LNG conversions and new-build vessels is higher, than for conventionally fuelled ships. Governments can help significantly to remove this barrier by providing commercial tools that will ease access to credit, or de-risk bank financing.
- **Diffuse Benefits:** is an interesting challenge, posed by the fact that the benefits of deploying LNG are not fully aligned with costs. For example, in the case of cargo vessels, fuel savings benefit the charterer, who pays for fuel, not the operator, who pays for the ship, so the latter's incentive to invest in LNG is diminished.⁴¹ This type of barrier is traditionally addressed by governments through providing incentives to the investors to close this gap, or by trying to better align costs with beneficiaries.
- **Resale value uncertainty:** is often cited as a barrier; however, if weighed against the alternative – the resale value of a diesel-fuelled ship in a regime of progressively stricter environmental regulations – the risk is likely exaggerated. Clear signals on future policy direction with regard to emissions regulation will help address this barrier.
- **Future fuel price uncertainty:** is as much a barrier, as it is a natural fact of life. Uncertainty in the cost of inputs, over long time horizons is a common business reality. Furthermore, uncertainty over the future price of LNG is no greater than for petroleum fuels, especially the low-sulphur distillates. For example, diesel pump prices have been historically increasing (see Figure 5), and diesel bunker fuel saw significant volatility throughout the past decade (See Figure 6), while the LNG commodity cost has dropped.

Figure 6

Historical Evolution of Market Indices and Conventional Bunker Prices



Source: Schinas, O. and M. Butler. Feasibility and Commercial Considerations of LNG-fueled Ships. Ocean Engineering (122) 84-96, 2016.

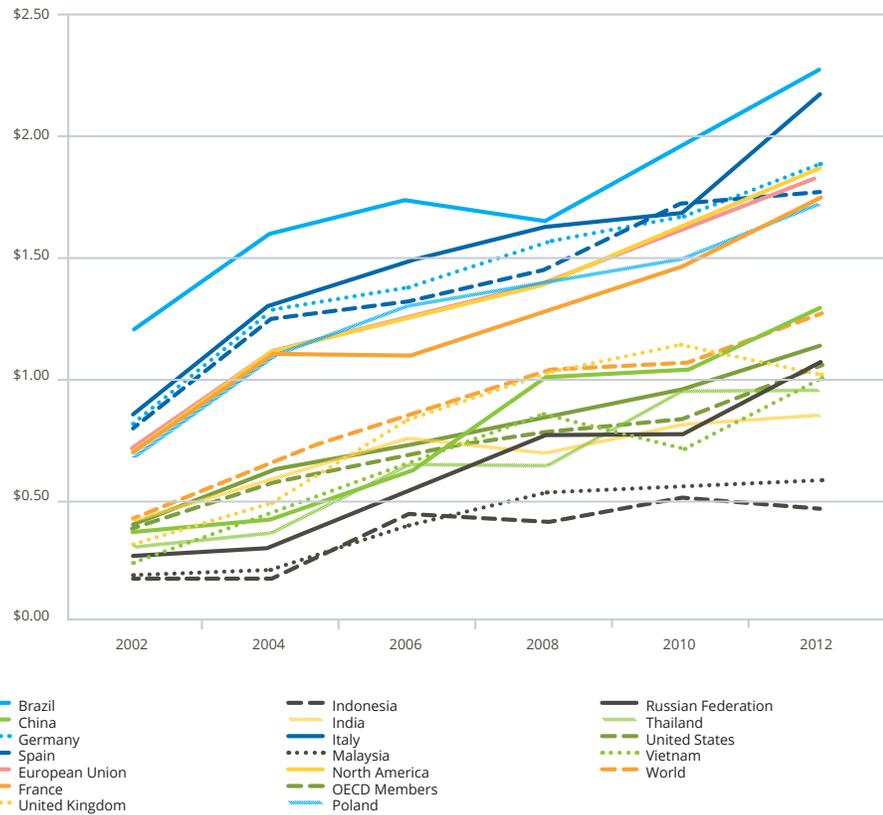
⁴⁰ Schinas and Butler, 2016

⁴¹ Schinas and Butler, 2016; DNV-GL, 2014

⁴² Ibid; IGU, 2014

Figure 5

Pump Price for Diesel Fuel, US\$ per litre, 2002-2012



Source: International Gas Union, (IGU). LNG as Fuel. Programme Committee D (Study Group 2), 2015.

Technical Barriers

• **Bunkering availability:** is one of the most frequently cited barriers in relation to LNG conversions. LNG bunkering for marine fuel use is currently in the early stages, and thus it is not as widely available globally, as conventional bunkering. There is a concern that this may impose additional costs on operators. This is the classical new technology 'chicken in the egg problem', where fleet operators are hesitant to switch because of lacking infrastructure, and ports are hesitant to invest because of uncertain demand.

This barrier is somewhat exaggerated, and there is already substantial bunkering capacity developing in the world. Europe has a requirement for all its major ports to have LNG bunkering by 2025. Asia, North America, and Australia are also taking steps to develop LNG bunkering.⁴³ Ports are also largely indicating the willingness to move quickly to support demand, once it begins to strengthen.

However, the first movers providing bunkering facilities will have to come up with the initial investment costs and accept the risk premium of uncertainty on the timing of demand.

Governments can help address this barrier for both operators and ports. For the former through policy commitments, similar to the European Union, which will provide assurance that infrastructure will be available to meet the need, and for the latter through sharing the risk of initial investments to accelerate the move to cleaner marine environment.

⁴³ Schinas and Butler, 2016; EC, 2014; IGU, 2015; Government of Japan, 2016

⁴⁴ Loyd's, 2014;

⁴⁵ IGU, 2015

A 2014 survey of 22 ports by Lloyd's Register, indicates 59% of ports already provide LNG bunkering infrastructure or have specific plans. Furthermore, 55% indicate the port is participating in the International Association of Ports & Harbours (IAPH) project to develop guidelines for LNG bunkering in ports.⁴⁴

European ports have done the most work in response to ECA emissions and sulphur limits. The Ports of Rotterdam and Zeebrugge will propose LNG bunkering with bunkering vessels. Qatar, Singapore, Japan, Thailand, China, UAE, USA and Canada among others are assessing LNG bunkering infrastructure.⁴⁵

Figure 7

LNG terminals in Europe: adapted from Energigas Sverige AB



#	Terminal	Country
1	Zeebrugge	Belgium
2	GATE/LBBR	The Netherlands
3	Isle of Grain	UK
4	Milford Haven	UK
5	Teesside	UK
6	Sines	Portugal
7	Swinoujscie	Portugal
8	Barcelona	Spain
9	Huelva	Spain
10	Cartagena	Spain
11	Sagunto	Spain
12	Bilbao	Spain
13	Mugardoz	Spain
14	Livorno	Italy
15	Panigaglia	Italy
16	Porto Viro	Italy
17	Fos Cavaou	France
18	Fos Tonkin	France
19	Montoir de Bretagne	France
20	Fredriksstad	Norway
21	Snohvit/ Melkøya	Norway
22	Risavika	Norway
23	Lysekil	Sweden
24	Nynäshamn	Sweden
25	Revithoussa	Greece
26	Marmara Ereğlisi	Turkey
27	Alaga Izmir	Turkey
28	Musel	Spain

- **“First Mover Tax”:** is a form of financial ‘penalty’ imposed on early technology adopters who have not had the benefit of learning from the others’ experience and mistakes. The operators and ports who are the first movers face higher costs; however, a significant portion of the benefits from their investments accrues to the public and those who follow in their footsteps.

- **New technology concerns:** are natural because the commercial application of LNG as marine fuel is relatively new; however, they are also somewhat exaggerated, as the technology is mature and all components are commercially available.⁴⁶ Decades of experience with LNG transport ships, which also used it as a fuel are supporting the development of codes and standards globally,⁴⁷ and growing experience with new applications of the fuel technology across the shipping industry will make this barrier obsolete.

- **Safety concerns:** decades of experience with shipping of LNG resulted in a solid foundation for safely operating LNG vessels and infrastructure. The LNG carrier industry has an excellent safety record, with no LNG-related fatalities in the 50 years of its existence.⁴⁸ These handling practices are now being translated into international safety codes and standards.

⁴⁶ West Coast Marine LNG Joint Industry Project Steering Committee, 2014

⁴⁷ Some examples include: International Code for the Construction and Equipment of Ships Carrying Liquid Gases in Bulk (IGC Code); International Code of Safety for Ships Using Gases or Other Low Flashpoint Fuels (IGF Code); Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Convention; International Safety Management Code (ISM Code)

⁴⁸ Ibid; DNV-GL, 2014

⁴⁹ DNV-GL, 2014

• **Impacts on space and range:** The extent of this impact as a barrier will strongly depend on individual vessel type, based on its size, engine, operational profile, among others. LNG fuel tanks are larger than conventional fuel tanks. However, vessels that will not be converting to LNG will also lose space and range, as they will have to install additional equipment (e.g. dual-fuel tanks, and exhaust cleaning systems) to comply with the new emissions caps.⁴⁹

Governments can help address all of the three barriers described above by supporting, or continuing to support, technology development, demonstrations and early deployments, in order to accelerate operational learning, collect data, and share lessons with new entrants.

Cultural

As in any similar situations, with a long-established industry facing a paradigm shift – in this case – fuel choice – the operators may be resistant to change. The cultural resistance to a less familiar fuel and technology is contributing to some of the perceived barriers, described above.

This barrier should gradually be eliminated, as the use of LNG-fuelled ships grows and becomes more mainstream. However, governments can help accelerate a cultural shift through improved communication about its benefits.

IV. POLICY CASE STUDIES

Government policy plays an immensely important role in improving air quality. It sets the regulatory framework for controlling harmful emissions, which weigh heavily on the technology choices the industry makes. In order to encourage the most environmentally-friendly choices, governments need to set clear and consistent policies and send effective signals, while addressing certain common market failures, such as costly pollution externalities.

Below is a number of examples from jurisdictions that provide policy guidance. The list is by no means exhaustive, but rather is meant to demonstrate the different range of actions available to decision makers at all levels, from local to national, to industry.

CHINA – The Case for Sub-National Leadership

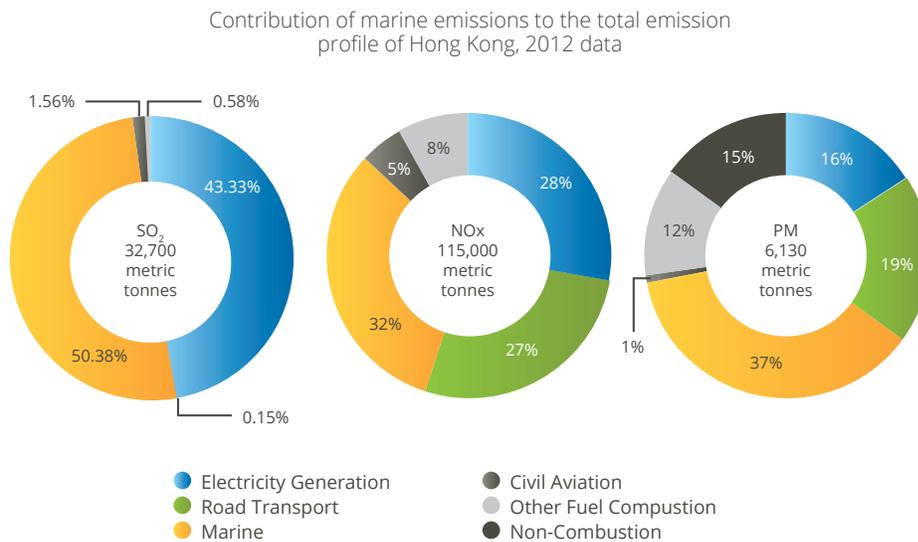
China has only recently started to move to controlling marine emissions. It is a signatory to the IMO; however, there was not much by way of national emissions regulation, until recently.⁵¹

The 2013 national Action Plan on Prevention and Control of Air Pollution became the impetus for adding a focus on marine sector emissions. In August 2015, the Ministry of Transport published an action plan on ship and port pollution control. The plan proposed to set up domestic emission control areas (DECAs) with a 0.5% limit on SO₂ in: Pearl River Delta (PRD), Yangtze River Delta (YRD), and the Bohai Rim. These were formalized in 2016, along with an implementation timetable: PRD comes into effect in January 2017, and by 2019 the limit should be enforced within 12 nautical miles from coastline of all DECA's.⁵²

The most interesting cases to consider in China; however, are those of regional initiatives that pre-dated the national regulation, spearheaded by Hong Kong in the PRD back in 2006, and by Shanghai in YRD.

Pearl River Delta Region is home to over 60 million people and 3 of the world's 10 biggest container ports (Shenzhen, Hong Kong, Guangzhou). Each of them suffers from significant air pollution and urban air quality problems, with shipping as a major contributor – responsible for roughly half of total SO_x emissions in Hong Kong.⁵³

Figure 8



Source: Fung, F., et al. Prevention and Control of Shipping and Port Air Emissions in China. Natural Resources Defense Council White Paper, 2014.

⁵¹ Fung, F., et., al., 2014

⁵² NG, S., 2016

⁵³ Ibid

Hong Kong took note of the serious problem of marine air pollution over a decade ago and established one of the leading marine pollution research programs, followed by targeted measures to curb it. It introduced a 0.05% cap on sulphur emissions for domestic vessels in April, 2014, followed by a 0.5% cap on all ocean-going vessels at berth in 2015.⁵⁴ It was the first jurisdiction in Asia to implement strict regulations on marine traffic. The positive results from Hong Kong's marine emissions control policy became evident quickly with a 50% reduction in SO₂ levels downwind of Kwai Chung Container Terminals, within just a year of implementation.⁵⁵

It led by example in taking pro-active measures, which were independent of the national government, and the other two cities in the PRD eventually followed with measures of their own. However, one of the lessons learned from the PRD example is that lack of regional coordination can undermine the effectiveness of individual initiatives – this was initially the case in PRD.⁵⁶

Shenzhen began formulating policy in 2013, with the release of its first Air Quality Enhancement Plan that set out targets for pollution reduction, including that from ships and port activities:

- Emissions from port equipment
- Sulphur control emission area at berth
- Encourage the use of LNG

The municipal government supported this plan by providing an incentive program for onshore power and marine fuel with low sulphur content (< 0.5%).⁵⁷ In 2016, Shenzhen too moved to implement the 0.5% cap on SO₂ emissions for ships at berth.⁵⁸

Guangzhou proceeded more cautiously with its Green Port Action Plan, where it laid out actions that focused more on demonstration and feasibility testing.⁵⁹

Yangtze River Delta (YRD) area ports also took a proactive approach by implementing the 0.5% limit on their own accord, prior to the national schedule. However, unlike in the latter case of PRD, a much more coordinated regional approach was taken, with Shanghai kicking it off. Effective April 2016, all ships berthing in Shanghai, Ningbo-Zhoushan, Suzhou, and Nantong are required to comply with the sulphur limit.⁶⁰

⁵⁴ Environmental Protection Department, the Government of Hong Kong Special Administrative Region (http://www.epd.gov.hk/epd/english/environmentinhk/air/air_maincontent.html)

⁵⁵ Environmental Protection Department, the Government of Hong Kong Special Administrative Region, 2016

⁵⁶ NG, S., 2016

⁵⁷ Ibid

⁵⁸ Environmental Protection Department, the Government of Hong Kong Special Administrative Region, 2016

EU Federal Policy Framework

The European Union has been far advanced on emissions regulation in both marine and land transport. It introduced its own marine sulphur emissions regulations that preceded the ECA under the Sulphur Emission Control Areas (SECA), designating the Baltic and North Seas, and the English Channel for reduced sulphur caps in 2005.⁶¹ It further has developed supporting policies for meeting emissions requirements via alternative fuels.

The EU is developing a robust policy framework to support the deployment of marine LNG fuel, recognizing its environmental advantages.⁶² The table on the following page describes two important components of the EU policy framework.

Due to its advancement, the EU is a rich source for operational learnings in LNG-fuelled vessels and bunkering technology. Currently, LNG fuel bunkering is available at seven EU sea ports and several ports in Norway, with additional plans to add LNG infrastructure by new entrants.⁶³

The EU conducted numerous studies to confirm that LNG as a shipping fuel offers long-term compliance with increasingly stringent maritime emissions standards.⁶⁴ It also introduced directives to deploy alternative fuels infrastructure, which include LNG, in order to support environmental and energy security goals. Europe considers natural gas in transport to support broader social objectives to improve “the security of Europe’s energy supply, support economic growth, strengthen the competitiveness of European industry, and reduce greenhouse gas emissions from transport.”⁶⁵

⁵⁹ Ibid

⁶⁰ NG, S., 2016

⁶¹ European Parliament, Directive 2005/33/EC

⁶² European Parliament, Directive 2014/94/EU; European Parliament, 2016

⁶³ TNO for EC, 2015

⁶⁴ Ibid

⁶⁵ European Parliament, 2016; TNO for EC, 2015

Policy	Description
<p>EU Alternative Fuels Directive (Directive 2014/94/EU)</p>	<ul style="list-style-type: none"> • Requires all member states to develop national policy frameworks for alternative fuels and infrastructure • Overall aim: “to establish a coherent policy framework that meets long-term energy needs of all transport modes by building on a comprehensive mix of alternative fuels” • Technologically neutral – removing regulatory and technical barriers to alternative fuels • Seeks the development of harmonized EU-wide standards and common technical specifications for enhanced interoperability • Provision of consumer information and awareness • LNG: One of the goals is to create a network of LNG fuelling points in major ports to facilitate shift to LNG • Directive specifies that decisions for location of the fuelling infrastructure must be based on a cost-benefit analysis, including environmental benefits. • Timelines for LNG bunkering deployment: <ul style="list-style-type: none"> • Maritime ports of TEN-T network by end of 2025 • Inland ports of TEN-T network by end of 2030
<p>Funding Support (Regulation No 1315/2013)</p>	<ul style="list-style-type: none"> • Specifies that LNG infrastructure is eligible for funding from the Connection Europe Facility (CEF) Fund • Under the CEF, 17 sources are made available to co-fund LNG infrastructure in the EU (e.g. the TEN-T or the Motorways of the Sea Programme.)⁶⁶



⁶⁶TNO for EC, 2015

US and the North American ECA – the case for LNG

The United States has also been a leader in introducing stricter emissions controls for marine traffic, as well as in providing a policy framework for the implementation of cleaner LNG fleet.

Some of the busiest world trade routes are into and within North America. Adopting LNG would allow the North American fleet to meet all of the environmental regulations, and the abundance of supply, combined with lower regional price, makes for an attractive business case. The environmental benefits offered by switching to LNG are vast and valuable in this region, particularly considering that most of North American domestic traffic passes through the Great Lakes.⁶⁷

International shipping activity is expected to continue growing in this region, thus the traffic density will increase. There is also strong interest in supporting the use of LNG in road and rail transport, which can create a unique opportunity for developing a multi-modal LNG transportation plan and benefit from economies of scale on infrastructure investment.⁶⁸

North American ECA came into effect on August 1, 2012. It includes the Pacific coast, the Atlantic/Gulf coast, and eight Hawaiian Islands, St. Lawrence Seaway, and the Great Lakes and rivers accessible to international shipping.⁷⁰



The North American ECA

According to the EPA, in 2030, emissions from ships operating in the ECA are expected to be reduced annually by 1,300,000 tons for SO_x, 1,200,000 tons for NO_x and 143,000 for PM 2.5. The benefits are expected to include preventing between 12,000 to 31,000 premature deaths and relieving respiratory symptoms for nearly five million people each year in the US and Canada. The monetized health-related benefits are estimated to be between \$110 and \$270 billion in the US in 2030.⁶⁹

On the policy front, the government and its agencies focused on updating regulatory structures to enable safe operation of LNG-fuelled ships, as well as providing direct support toward technology development and first-mover conversions. For instance, the federal Department of Transportation's Maritime Administration and US Coast Guard (USCG) conducted a study on the regulatory approval process for LNG bunkering and the associated operational risk and safety mitigation.⁷¹ In 2015, the USCG released its LNG bunkering guidance for LNG bunkering, personnel training, and Waterfront facilities, and work is underway to complete the development of complete regulatory framework.⁷

⁶⁷ IMO, 2016

⁶⁸ Ibid

⁶⁹ IMO, 2016

⁷⁰ Ibid

⁷¹ Thompson, 2016

⁷² DNV-GL <https://www.dnvgl.com/news/us-coast-guard-completes-lng-bunkering-regulations-with-reference-to-dnv-gl-s-recommended-practice--18653>

There has been some notable activity in the North American LNG vessel market, with many projects announced, or under way. In 2015, of the 40 LNG merchant ships globally, 15 were in North America.

The shipping sectors below are likely candidates for transition to LNG fuel in the short term.

Bulk carriers operating in the Great Lakes: U.S. company Interlake Steamship Co. intending to convert 7 ore-carrying vessels to LNG

Container ships: TOTE Inc. ordered a conversion of 2 existing ships operating between the Pacific Northwest and Alaska, signed a contract for 2 new 3100 TEU ships, with an option for 3 more

Ferries and cruise ships: one of several projects is by Canadian Société des traversiers du Québec ordered 3 car ferries to run on the St Lawrence waterway.

Source: IMO, 2016

Japan – Interjurisdictional Cooperation

In October 2016, the governments of Japan and Singapore, along with a number of key international ports, signed a memorandum of understanding (MOU) forming a Network of Ports and Maritime Administrators, to develop the world's first harmonized LNG bunkering standards.⁷³ The vision behind the MOU "is to form a network among LNG bunkering bases and promote the conversion of ship fuel from heavy oil to LNG by harmonizing standards and specifications related to LNG bunkering." The signatories include:

- Ministry of Land, Infrastructure, Transport and Tourism, Japan,
- Maritime and Port Authority of Singapore,
- Ulsan Port Authority,
- Antwerp Port Authority,
- Port of Zeebrugge,
- Port of Rotterdam Authority,
- Norwegian Maritime Authority,
- JAX Chamber

⁷⁴

Japan is uniquely positioned for LNG bunkering, since it already has extensive infrastructure for importing the fuel. The government recognizes its potential for becoming a leader in this sphere, and it is positioning the Port of Yokohama as a model for developing LNG bunkering capabilities. Importantly, it is coordinating its activities with Singapore – one of the main global bunkering hubs, and the second largest container port in the world.⁷⁵

⁷³Joint Press Release, <https://www.mlit.go.jp/common/001148234.pdf>

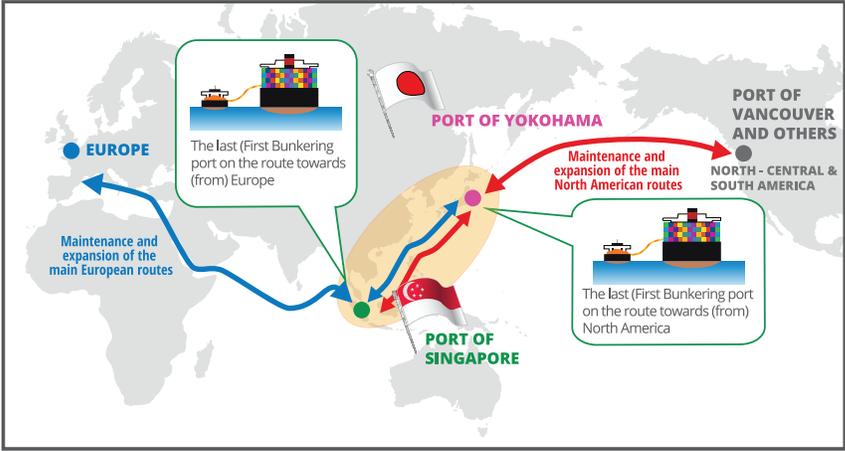
⁷⁴The Ministry of Economy, Trade and Industry, Japan https://www.mlit.go.jp/en/report/press/port02_hh_000001.html

⁷⁵Steering Committee for LNG Bunkering at the Port of Yokohama, 2016

The government began a policy supporting implementation of LNG fuelled ships in 2012. It developed a roadmap for enabling and promoting LNG bunkering business in the Port of Yokohama, which is home to two LNG import terminals, and views it as a valuable economic opportunity. The first LNG bunkering vessel was introduced by Japan in 2015 and will provide significant learning opportunities for future expansion.⁷⁶

The diagram below demonstrates the potential international LNG bunkering network. Under the vision of this network, Singapore would become the bunkering hub for Southeast Asia or Europe-bound, and Japan would be the east Asia hub for North America-bound vessels.

Formation of LNG bunkering hubs by collaboration between the Port of Yokohama and the Port of Singapore



Source: Ministry of Land, Infrastructure and Tourism (Japan). Press Release: Building international cooperation on the development of LNG bunkering hub. October 6, 2016.

Singapore is the largest conventional bunkering port in the world, and it views making LNG bunkering available as a critical requirement to maintain this global leadership position. In this vein, Singapore opened a large LNG import terminal 2014 and has been developing LNG bunkering for deep-sea ships. It will offer ship-to-ship bunkering, in order to serve the large vessels that it hosts.⁷⁷

⁷⁶ Ibid
⁷⁷ West Coast Marine LNG Joint Industry Project, 2014

Sampling of International Programs Supporting LNG fuelled shipping

Government Policies

EU	TEN-T (Trans-European Transport Network): subsidies are provided for LNG fuel deployment in ships for up to 50% of project cost. ⁷⁸
Norway	NOx taxation in place since 2007. Government established NOx Foundation in 2008 supporting 80% of fuel conversion to LNG. ⁷⁹
US	Government provided 324.6 million loan guarantee through the Federal Ship Financing Program for the construction of the world's first two LNG powered container ships. Also, invested 900,000 for remodelling an existing RORO vessel into LNG, in order to collect operational data. ⁸⁰
Singapore	Maritime and Port Authority runs a pilot program for establishing LNG bunkering operations and provides a subsidy of 2 million Singapore dollars (roughly USD 1.4 million) per ship for LNG ship construction, as well as an exemption from port facility fee for 5 years for LNG-fuelled ships. ⁸¹
Korea	2.4 billion fund – “New ship Building Support program” available for LNG ship construction. Providing indirect subsidies through tax benefits and port fee exemptions. Planning to revise regulatory frameworks to make compatible with LNG fuelled ship operations. The government allocated 510 million USD to the construction of LNG bunkering facility in Busan. ⁸²

Port Initiatives

Significant activity has been taking place to support clean air at the sub-government level. Port Authorities recognize the value of clean marine vessels and implement measures to incentivize them.

The Port of Rotterdam is rapidly developing LNG fuelling infrastructure aspiring to be the European leader in this space. The Port is starting with a tanker-truck delivery, and later adding a shore-to-ship facility.

⁷⁸ Steering Committee for LNG Bunkering, 2016

⁷⁹ Ibid

⁸⁰ Ibid

⁸¹ Ibid

⁸² Ibid

Rotterdam pioneered regulating the technology and safety for LNG bunkering. In fact, it had a regulatory framework in place, ahead of the first fuelling operation.⁸³

Since 2014, the Port Management By-Laws of the port of Rotterdam were updated to make it Rotterdam the first port where ship-to-ship LNG bunkering of seagoing vessels is officially allowed. Truck-to-ship bunkering of inland vessels was already possible before that.⁸⁴

The **Environmental Ship Index** (ESI) is a measurement based on the World Port Climate Initiative, which ranks environmental performance of ships, and those that outperform the minimum emission standards by most, get the highest rankings. Many ports apply a special tariff scheme or other benefits, based on the ship's ESI.⁸⁵ A selection of examples is listed below.

Port of Hamburg	Offers a rebate based on Ship's ESI ⁸⁵
Rotterdam	Awards "Green Trophy" for a ship's ESI and a discount to LNG ships ⁸⁶
Singapore	Offers extensive incentives for clean ships. Three different programs: "Green ships" – rewards the most efficient ships with significantly reduced fees and tax exemptions; "Green Port" – incentivizes ships with reduced GHG profiles; and "Green Technologies" – supports local companies to invest in cleaner technologies. ⁸⁷
Canada West Coast	Canada's West Coast, PMV provides an incentive for future LNG-fuelled ships through its EcoAction program, which reduces harbour dues by 47% for LNG vessels that qualify for the program's Gold level ⁸⁸ .

⁸³ Schinas and Butler, 2016

⁸⁴ Port of Rotterdam Authority, 2017

⁸⁵ Schinas and Butler, 2016

⁸⁶ Ibid

⁸⁷ Ibid

⁸⁸ West Coast Marine LNG Joint Industry Project, 2014

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