BUSINESS
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Developing Liquefied Natural Gas (LNG) Bunkering in Hong Kong

August 2021

Executive Summary

The shipping industry is crucial to international trade and economic development. However, it is also one of the major emitters of air pollutants and greenhouse gases. With calls from the International Maritime Organisation (IMO) to decarbonise shipping and to control ship-induced air pollution through the tightening of regulations, the international shipping community has been making effort to improve ship design and fuel efficiency and to look for cleaner fuels as an alternative to conventional fuel oil.

Among several alternative marine fuels that meet local regulatory requirements, liquefied natural gas (LNG) is holding an edge over others in terms of commercial readiness, technical maturity, fuel availability, safety, emission reduction, and costs. While LNG is not carbon-free and requires extra measures to control methane slip, it brings significant reduction in air pollutant emissions and up to about 21% reduction in greenhouse gas emissions. LNG will have a major role to play as a transition fuel until other zero-carbon solutions become market-ready.

In Hong Kong, the Government recently pledged to achieve carbon neutrality by 2050. To support such ambition, there are calls from the shipping sector and business associations in the past years to promote the use of LNG as marine fuel for ocean-going vessels. A key part of it is to develop LNG bunkering in Hong Kong to unlock the full potential and benefits of LNG and strengthen Hong Kong's position as a leading bunkering port, a major hub port in the region, and one of the international maritime centres in the Greater Bay Area.

The LNG receiving terminal currently under construction will become an important component of the LNG value chain, putting Hong Kong in a strong position to develop LNG bunkering. For the downstream distribution of LNG, ship-to-ship bunkering will offer most flexibility to Hong Kong in terms of capacity, bunkering location, and land requirements. To plan and develop LNG bunkering in Hong Kong, it is necessary and important for the Government to put together a regulatory framework as soon as possible that covers aspects such as licensing, safety, personnel competence, environment and sustainability, and simultaneous operations.

LNG bunkering has a compelling safety record largely due to collaborative efforts among the industry, port authorities, and international agencies in developing and complying with suitable guidelines and stringent standards over the years. International references provide a ready source of practical policies and procedures that could be considered and adopted in developing appropriate regulations and guidelines for local use. Among an array of resources, it is recommended that the Hong Kong Government should rigorously review the following documents:

European Maritime Safety Agency (EMSA)
- Guidance on LNG Bunkering to Port Authorities and Administrations

International Association of Ports and Harbors (IAPH)
- LNG Bunker Checklist – Ship to Ship

International Maritime Organisation (IMO)
- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code)
- International Ship and Port Facility Security (ISPS) Code
- International Convention for the Safety of Life at Sea (SOLAS)
- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

The Society for Gas as a Marine Fuel (SGMF)
- Bunkering of Ships with LNG – Competency and Assessment Guidelines
- Operation of Ships with LNG – Competency and Assessment Guidelines
- Safety Guidelines – Bunkering
- Simultaneous Operations (SIMOPS) during LNG Bunkering

With the Government announcing its intention to take forward the adoption of LNG in ocean-going vessels and to actively explore the use of the offshore LNG terminal as a bunkering facility for vessels, the planning for bunkering areas and the formulation of technical and safety regulations and requirements through preliminary studies and engagement with the industry stakeholders should become a priority. In addition to developing a regulatory framework, the Government can also start introducing policies that would incentivise and attract LNG-fuelled ships to berth and bunker in Hong Kong, to further maintain Hong Kong's competitiveness as a hub port and expedite the decarbonisation of shipping in the short to medium term.

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1 | Introduction

1.1 International shipping, climate change and air pollutant emissions

Maritime transport is the backbone of international trade and the global economy. Around 80% of global trade by volume and over 70% by value are carried by sea[1]. However, maritime transport is also negatively impacting the environment in many ways. For example, the international shipping sector contributed around 2.9% of global anthropogenic carbon emissions in 2018 according to the International Maritime Organisation (IMO)'s 4^{th} Greenhouse Gas (GHG) Study. IMO also stated there was a 9.6% rise in GHG emissions in 2018 compared to 2012 levels[2]. In addition to GHG emissions, commercial shipping also contributes significantly to local air pollution in port cities because of the popular use of crude oil derived bunker fuel by ships.

Under the Annex VI of the *International Convention for the Prevention of Pollution from Ships* (the MARPOL Convention) of the IMO, the global limit for sulphur content in fuel oil used on board of ships was reduced from 3.5% to 0.5% m/m (mass by mass) in 2020 as a way to reduce the shipping sector's impact on air pollution. In IMO designated emission control areas (ECAs), a

[1] https://unctad.org/system/files/official-document/rmt2018_en.pdf

[2] https://www.researchgate.net/publication/281242722_Third_IMO_GHG_Study_2014_Executive_Summary_and_Final_Report

far more stringent sulphur content requirement for marine fuels has been set at 0.1% m/m since 2015. IMO also adopted a GHG reduction strategy in 2018 with ambitious targets[3] to reduce the shipping sector's carbon intensity by 40% by 2030 and 70% by 2050. In absolute terms, IMO's strategy aims to reduce at least 50% of annual GHG emissions (approximately an 85% reduction per ship) by 2050 compared to 2008 levels. The international shipping community has continuously been making effort to reduce the sector's environmental impact, targeting to be ahead of IMO's requirement – which is very encouraging. Hong Kong must keep apace of such efforts to not lag behind the international community.

Locally, ships have been the major contributor to air pollution in Hong Kong[4]. To reduce the emissions of sulphur dioxide (SO_2) and particulate matter (PM) from ships, the Government has required ocean-going vessels to switch to fuel with a low sulphur context (0.5%) at berth since July 2015, and the fuel-switching mandate was extended to cover all of Hong Kong waters in 2019 in order to align with the establishment of the Pearl River Delta Domestic Emission Control Area[5] by the Ministry of Transport in China. Little has been done, however, to reduce carbon emissions from ships, as the local shipping sector is relatively small and its impact on climate change is insignificant compared to other sectors like power generation[6].

The Government's pledge in November 2020[7] to become carbon neutral by 2050 is a game changer as all sectors will have a role to play in decarbonisation, including the shipping sector. Even though GHG emissions from international shipping falls outside the scope of the Paris Agreement, Hong Kong companies may still focus efforts to reduce emissions from their supply chains – with international shipping often being a major component of them – to stand any chance of achieving net zero.

It is generally acknowledged that ship design and fuel efficiency would be important to decarbonise the shipping sector. However, even by improving energy efficiency of ships through the current framework, including the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), it is still insufficient for ships to reach the 2050 target set by IMO. At least 50% of the overall reduction effort will have to come from fuels and other innovative measures. Hence, the shipping sector is looking for cleaner fuels as an alternative to conventional fuel oil.

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[3] https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/IMO%20ACTION%20TO%20REDUCE%20GHG%20EMISSIONS%20FROM%20INTERNATIONAL%20SHIPPING.pdf

[4] In 2018, shipping accounted for 49% of sulphur dioxide (SO_2), 37% of nitrogen oxides (NO_X), 34% of respirable suspended particles (RSP) and 41% of fine respirable particles (FSP) in Hong Kong according to the Environmental Protection Department https://www.epd.gov.hk/epd/english/environmentinhk/air/data/emission_inve.html

[5] https://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/guide-air-pollution-control-fuel-for-vessels-regulation.html

[6] According to EPD's sectoral GHG emissions inventory, 65.7% of greenhouse gas emissions were contributed by electricity generation and other energy industries in 2019. Transport also accounted for 18.1%, in which local vessels such as ferries made insignificant contribution due to the small scale of operation relative to road-based transport. The Government is also conducting trials on green ferries run by electricity or other forms of clean energy (see footnote 7), but the main driver is to reduce air pollution. https://www.climateready.gov.hk/files/pdf/Greenhouse%20Gas%20Emissions%20in%20Hong%20Kong%20by%20Sector.pdf

[7] https://www.policyaddress.gov.hk/2020/eng/p125.html

1.2 LNG as a marine fuel

Table 1 below compares a number of alternative marine fuels and provides a high-level overview of their advantages and limitations, while Figure 1 illustrates DNV's assessment of the current viability of alternative fuels in different aspects, where a green circle means viable and a red one means immature.

Table 1. High-level overview of alternative marine fuels

	Pros	Cons
Liquefied Natural Gas (LNG)	• Mature, established technology and supply chain • Non-toxic • Low air emissions • Competitive fuel price • Cleanest alternative fuel available today	• GHG emission benefits largely dependent on the level of methane slip (see Box 1 on p.6) • Needs to be kept and transported under cryogenic conditions
Liquefied Petroleum Gas (LPG)	• Non-toxic • Competitive fuel price	• Limited GHG emissions benefits if not produced renewably or with carbon capture and storage • Limited maturity for maritime usage
Methanol	• Mature and established supply chain	• Limited GHG emissions benefits if not produced renewably or with carbon capture and storage • Supply chain not established for methanol as a marine fuel • Mildly toxic
Biofuels	• Low GHG emissions and reduced air pollutant emissions • Able to be used as a drop-in fuel • Can utilise existing distribution systems	• High production cost • Low production quantity • First generation biofuel competes with food production
Ammonia	• Potential to be zero emissions and has a slightly higher energy density than hydrogen • Shipping infrastructure can be used interchangeably with some other fuel products	• High capital cost and lack of bunkering infrastructure • Low maturity • Low energy density • Highly toxic
Hydrogen	• Potential to be zero emissions if produced renewably or with carbon capture and storage • Non-toxic	• High capital cost and lack of bunkering infrastructure • Low energy density • Low ignition energy • Flammability
Battery Electric	• Zero emissions during operation, potential to be zero emissions depending on the electricity grid • Mature technology and manufacturing process • Rapidly decreasing battery prices	• Low power density and limited feasibility beyond short sailing distances • Dependent on high-power charging infrastructure

Sources: Comparison of Alternative Marine Fuels, DNV; Alternative Fuels Insight, DNV; Forecasting the Alternative Marine Fuel: Ammonia, Korean Register

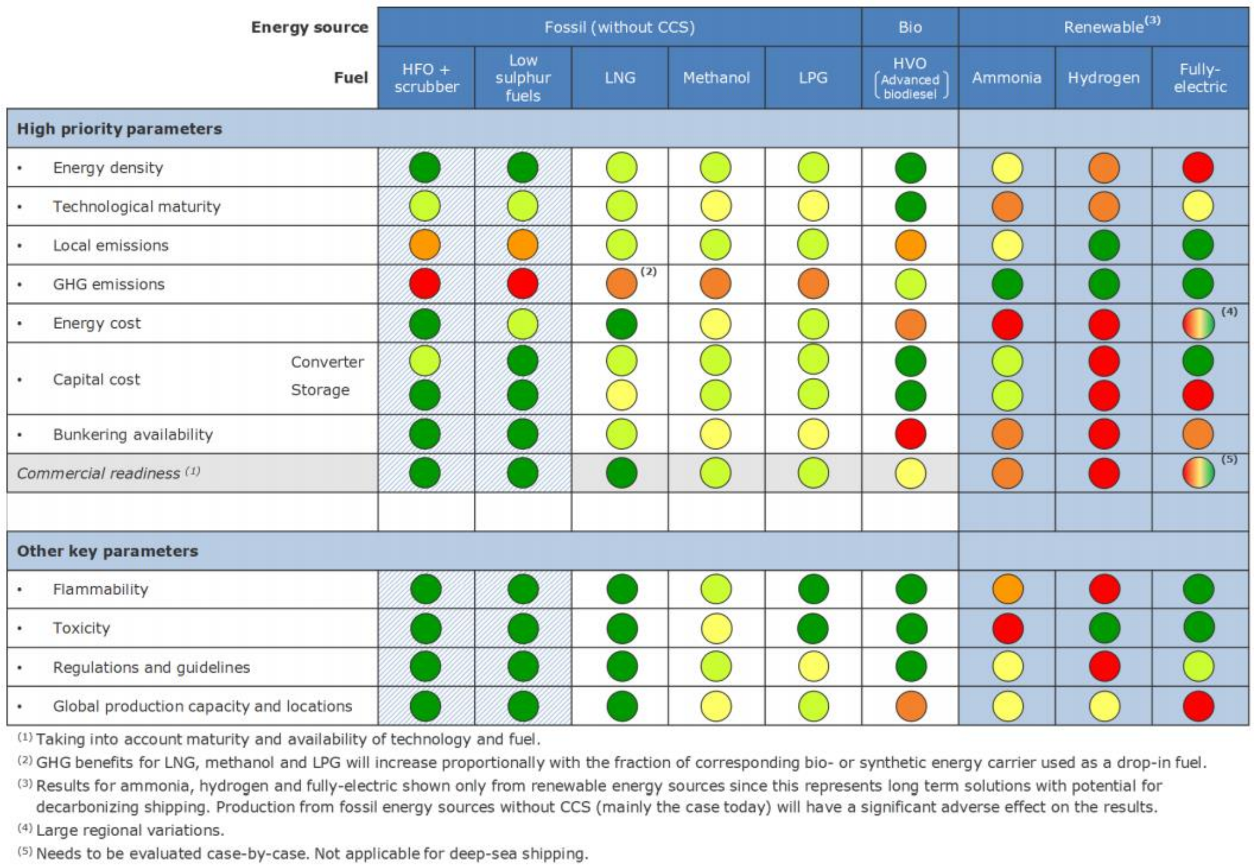

Figure 1. Comparison table of the commercial and operational viability of alternative marine fuels

Source: Comparison of Alternative Marine Fuels, Figure 7-1, DNV

In most major international ports, emerging alternative fuels that meet local regulatory requirements and policy aspirations are either not yet market-ready or have limited fuel production capacity. The shipping sector usually considers technological maturity and fuel availability as the key determining factors in taking actions and investment decisions. Among the fuel options listed in Figure 1 that are currently available to the shipping industry at scale, LNG is the most technologically mature and the least carbon intensive fuel. LNG is competitive against other fuel options in terms of commercial readiness, technical maturity, fuel availability, safety, emission reduction, and costs.

LNG is a fossil fuel and comprises mainly of methane and other hydrocarbons, produced through liquefaction of natural gas. As natural gas only condenses into liquid at cryogenic temperatures (-162°C) at atmospheric pressure, LNG is commonly stored at temperature of around -160°C at atmospheric pressure. LNG has a relatively low energy density compared with fuel oil which is widely used in the marine sector, so roughly 1.8 times more LNG is needed to be bunkered to achieve the same range compared to bunkering heavy fuel oil (HFO)[8]. Ship owners may therefore

[8] https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_LNG_Bunkering_Advisory.pdf

decide to bunker more frequently if they prefer to use the hull volume to carry the cargoes versus using the space for bigger or additional gas tanks.

A key attribute of LNG is safety. LNG is easy to transport, poses minimal risk to the marine environment, has a low flammable range, and is non-toxic. Effective regulations, standards and guidelines for safe operation are already in place worldwide, and LNG has been shipped around the world for more than 50 years, with more than 100,000 commercial LNG cargoes delivered without any major incidents at sea or in ports[9]. However, as with any commercial shipping fuels[10], not following the guidelines do present health and safety hazards. Therefore, LNG must be treated with care, in terms of maintaining the equipment onboard in good operating conditions and adopting industry best practice procedures. Nonetheless, various precautionary measures throughout the LNG value chain are already in place and special equipment are employed to ensure the fuel is properly stored and handled.

Comparing with HFO, LNG is cleaner and can reduce emissions of carbon dioxide (CO_2), SO_2, nitrogen oxides (NO_X) and PM. LNG's well-to-wake emission of GHGs can be reduced by up to 20% versus marine gas oil (MGO) and 21% versus HFO[11]. The degree of GHG reduction depends on the degree of methane slip during the natural gas production and combustion process. As methane is a potent short-lived GHG, mitigating methane slip is crucial (see Box 1 below for more information on methane slip).

The use of LNG as marine fuel started in the early 2000s, spearheaded by the Scandinavian countries. Additionally, the IMO 2020 regulation gathered momentum on the global adoption of LNG as a marine fuel. To date, many shipyards around the world have the capability to build and service LNG fuelled ships, supported by a network of original equipment manufacturers (OEMs) and Classification Societies. Operational experience accumulated by LNG bunker operators have also resulted in the development of comprehensive guidelines for new players to follow, gradually expanding a network of industry peers who can contribute to the continuous improvement of the practice. The two decades of development put LNG ahead of alternative marine fuels on supply chain maturity, hence its acceptance by ship owners and operators.

In terms of costs, as natural gas prices remain competitive in recent years[12], DNV estimated that LNG vessels could be paid back in 5 to 7 years[13] depending on the vessel type. Regarding fuel cost reduction, as a reference point, the container vessel *Wes Amelie* reported savings of over

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[9] https://giignl.org/sites/default/files/PUBLIC_AREA/Publications/giignl_-_2020_annual_report_-_04082020.pdf

[10] LNG is stored at a very low temperature, which may cause fracture damage if in contact with steel; skin contact with LNG can also inflict cold burn. Due to heat leakage through the insulation of the fuel tanks, LNG in storage evaporates and gives off natural gas constantly. Although LNG itself is not flammable and explosive, it is highly flammable in its vapour stage. Furthermore, if the concentration of methane is high enough in the air, personnel in the immediate area may suffer from asphyxiation.

[11] https://3gry456jeet9ifa41gtbwy7a-wpengine.netdna-ssl.com/assets/ts-SEA-LNG-and-SGMF_GHG-Analysis-of-LNG_Full_Report_v1.0.pdf

[12] https://www.dnv.com/maritime/insights/topics/lng-as-marine-fuel/current-price-development-oil-and-gas.html

[13] https://www.dnv.com/maritime/webinars-and-videos/on-demand-webinars/access/LNG-fuel.html

US$ 3,000 per day in 2019 using LNG instead of MGO[14]. The white paper produced by Gibsons and Channoil Consulting[15] also shows that if LNG pricing is to remain competitive versus conventional marine fuels, it would be more economical for ships to use LNG. If carbon pricing

Box 1. Methane Slip

LNG is a relatively clean fossil fuel compared to conventional fuel oils widely used in the shipping sector. It has proven air pollutant and greenhouse gas emission reduction benefits. However, LNG's main component, methane, is a potent greenhouse gas 84 times stronger over a 20-year time horizon and 30 times stronger over a 100-year time horizon when compared to the global warming potential of CO_2.

Given the tendency for LNG to boil off or evaporate, methane can be unintentionally released along the LNG value chain, for example in upstream production processes or during fuel combustion. This release of methane into the atmosphere is also known as methane slip. Combined with the high global warming potential of methane, the inherent carbon reduction benefit of LNG as an alternative fuel may be diminished and has given some people the perception that LNG may not be a viable solution for reducing carbon emissions from shipping.

While the amount of methane slip is largely dependent on the type of on-board engine, existing engine technologies using LNG are already capable of reducing well-to-wake emissions (life-cycle emissions from fuel production, refining, transportation and combustion) by 14% to 21% compared with HFO and MGO. The industry is aware of this issue and is actively searching for ways to reduce methane slip in engines.

Original equipment manufacturers have indicated that engine design changes, together with new solutions for post treatment and the transfer of technology from high-performance two-stroke engines to four stroke engines have the potential to reduce methane slip by up to 90%. For example, Wärtsilä has reduced methane slip from their dual-fuel engines by 85% by optimising engines and leakages[1]; MAN Energy Solutions has existing engines that reduce methane slip by 50%[2] and could achieve a 90% reduction potential through engine design and control improvements, the use of catalysts and direct gas injection[3].

Looking upstream, more than 20 international oil and gas companies signed on to the set of Methane Guiding Principles[4], a voluntary partnership with 5 guiding principles that aims at reducing methane emissions across the natural gas value chain, increasing transparency, and advocating for policies and regulations. Companies have also set individual methane emissions intensity targets. Shell, for example, has committed to control the methane emissions intensity along their supply chain to less than 0.2% by 2025[5].

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1 https://www.wartsila.com/insights/article/mind-the-methane-gap
2 https://www.man-es.com/marine/products/megi-mega/me-ga
3 https://people.man-es.com/docs/librariesprovider51/default-document-library/technical-paper.pdf?sfvrsn=1f9ed3a2_4
4 https://methaneguidingprinciples.org/
5 https://reports.shell.com/sustainability-report/2019/sustainable-energy-future/managing-greenhouse-gas-emissions/methane-emissions.html

or other market-based measures are to be introduced to the marine sector[16,17], LNG would appear even more cost efficient.

Switching to LNG alone is not sufficient to help the marine sector achieve the IMO's 2050 carbon emission reduction target, but it is expected to play a major role as a transition fuel in the shipping sector's decarbonisation journey as LNG is the only market-ready and scalable low carbon marine fuel available now to decarbonise the sector. A report published by Thinkstep estimated that if ships replaced HFO and MGO fuels with LNG, the global fleet could reduce their GHG emissions by 11% to 18% at once[18]. As GHG emissions stay in the atmosphere for a prolonged period, early transition and decarbonisation of the shipping sector will bring multiplied benefits over time.

1.3 Latest development of LNG bunkering worldwide

The size of the LNG bunkering market has more than doubled over the past decade. During the past three years, the growth of LNG volumes as a marine fuel has exceeded 10% annually. By 2035, global LNG demand is expected to increase by 90% or even double[19]. LNG was originally most widely adopted in Europe, but with the tightening of international marine regulations regarding emissions and rising expectation on the sector to decarbonise, the adoption of LNG as a marine fuel has grown rapidly in other parts of the world. Currently, there are 202 LNG-fuelled trading vessels operating globally and 227 dual fuel ships are on order, in addition to the 601 vessels in the global LNG carrier fleet[20]. Compared to 114 in early 2020, 124 ports are now offering LNG bunkering services and it is predicted that by 2022, 170 ports will provide such services[21], and it is expected that there will be around 1,000 LNG fuelled vessels globally by 2030[22]. In Asia-Pacific, countries such as South Korea, Japan, Malaysia, China, and Singapore have all constructed or started to build LNG bunkering vessels to perform ship-to-ship bunkering in key ports.

In Hong Kong, there are calls from the shipping sector and business associations in the past years to promote the use of LNG as marine fuel for ocean-going vessels and to develop LNG bunkering in Hong Kong. More recently, the Council for Sustainable Development submitted a report to the Government on long-term decarbonisation strategy and amongst the recommendations, LNG was highlighted as a market-ready transition fuel for Hong Kong. In the new *Clean Air Plan for*

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14 http://www.conferenzagnl.com/2020/06/nel-2019-portacontainer-wes-amelie-risparmia-1-mln-grazie-a-gnl/?lang=en

15 https://splash247.com/the-consensus-for-an-effective-carbon-price-for-shipping/

16 https://www.argusmedia.com/en/news/2141385-parliament-votes-eu-ets-ship-inclusion

17 https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

18 https://3gry456jeet9ifa41gtbwy7a-wpengine.netdna-ssl.com/assets/ts-SEA-LNG-and-SGMF_GHG-Analysis-of-LNG_Full_Report_v1.0.pdf

19 https://www.mckinsey.com/industries/oil-and-gas/our-insights/winning-the-race-for-world-class-lng-optimization-capabilities

20 https://www.statista.com/statistics/468412/global-lng-tanker-fleet/

21 https://www.seatrade-maritime.com/bunkering/shippings-green-investment-gaining-traction-says-clarkson

22 https://uk.reuters.com/article/oil-appec-bunker/lng-fuelled-tankers-to-more-than-double-by-2030-petronas-exec-idUSL4N2GD0SK

Hong Kong 2035, the Government also made clear its intention to take forward the adoption of LNG in ocean-going vessels and to actively explore the use of the offshore LNG terminal as a bunkering facility for vessels, including the planning for LNG bunkering areas and the formulation of technical and safety standards and requirements for offshore LNG bunkering in the coming years.

In the next chapter, the benefits of LNG bunkering in Hong Kong will be discussed.

2 | Benefits of LNG Bunkering in Hong Kong

2.1 LNG demand mapping for Hong Kong in the marine sector

Hong Kong is one of the world's major seaports. In 2019, there were 25,388 ocean-going vessel arrivals and the port handled a total of 161 million tonnes of cargo[23] (Figure 2).

[23] https://www.statistics.gov.hk/pub/B10200082020QQ03B0100.pdf

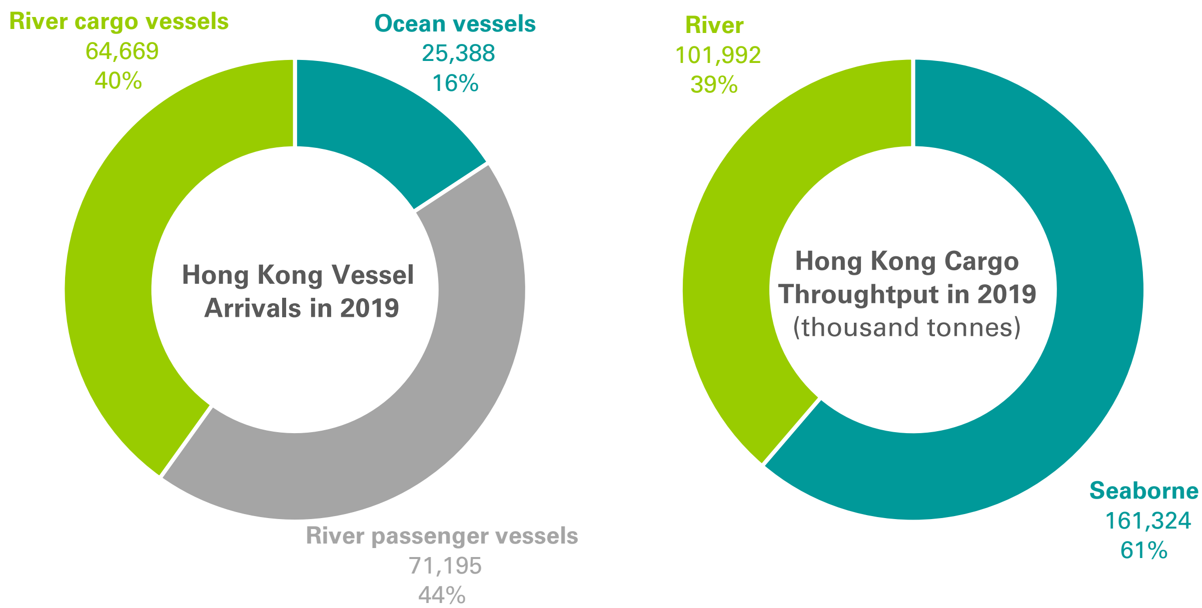

Figure 2. Hong Kong vessel arrivals and cargo throughput

Source: Hong Kong Shipping Statistics, Census and Statistics Department

Hong Kong is also a leading bunkering port in the world, with annual bunker sales volume of around 6.67 million metric tonnes (mt) in 2019[24]. While there is no publicly available fuel consumption data of ocean-going vessels arriving in Hong Kong, it is reasonable to assume that the majority of the vessels are still using fuel oils and very few of them will use LNG. Nonetheless, adding LNG as a product in Hong Kong's bunkering service will certainly draw ship visits. For example, the cruise sector has placed new orders of LNG-fuelled ships in recent years. As the cruise industry is planning their routing and schedules in the Asian market for the coming years, having LNG bunkering in Hong Kong early will definitely attract some of those cruise ships to include Hong Kong in their route planning. Citing another example, many large container vessel newbuilds destined to go on intercontinental routes are LNG-fuelled and would only call at major seaports, the availability of LNG for refuelling is likely going to be one of the essential services they require while at port, and losing this to other ports in Asia would marginalise Hong Kong's status as a major seaport, which could also risk the current suite of marine-related services being offered in the city heading towards a downward spiral. In other words, there is a significant upside on the demand of LNG from ships calling at Hong Kong. Potentially, Hong Kong may also attract bunker-only call ships given the port's strategic location.

[24] https://www.statistics.gov.hk/pub/B11000022019AN19B0100.pdf

2.2 Economic benefits

The maritime and port industry contributed HK$29.5 billion to Hong Kong's gross domestic product (GDP) in 2018 (Figure 3). This represented 1.1% of the overall output of the economy[25] and 2.1% of all employed persons[26].

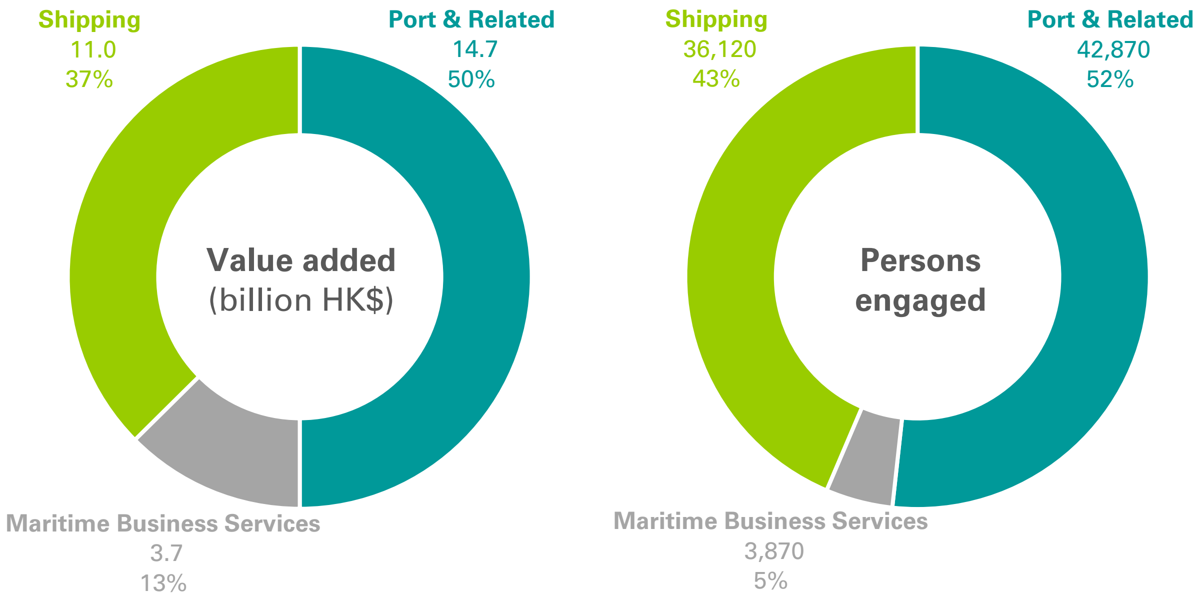

Figure 3. Economic contribution of the Hong Kong maritime and port industry

Source: Study on the Economic Contribution of Maritime and Port Industry in 2018, Hong Kong Maritime and Port Board

The global LNG bunkering market was valued at around US$400 million in 2017 and projected to increase to about US$12 billion by 2024[27]. As explained in the previous section, developing LNG bunkering in Hong Kong will attract more ships (and therefore the crew and in the case of cruises, the passengers) to the port and unlock tremendous economic opportunities for Hong Kong. This will also create employment opportunities within the sector and strengthen Hong Kong's position as a major hub port in the region and one of the international maritime centres in the Greater Bay Area.

2.3 Environmental benefits

Shipping continues to be the largest local source of air pollution in Hong Kong. As it is well documented that LNG can reduce SO_2 emissions by almost 100% and the emissions of NO_X and

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[25] https://www.hkmpb.gov.hk/document/Study_on_Economic_Contribution_of_Maritime_and_Por.pdf

[26] https://www.censtatd.gov.hk/hkstat/sub/sp200.jsp?tableID=006&ID=0&productType=8

[27] https://www.zionmarketresearch.com/news/lng-bunkering-market

PM by over 80%, the development of LNG bunkering in Hong Kong will hopefully improve the marine sector's access to the fuel, and hence accelerate the use of LNG as marine fuel to bring significant air quality improvement benefits to society.

Similarly, the use of LNG would also reduce GHG emissions from ships, but the level of reduction, ranging from 4% to 21% compared to using MGO and HFO, depends on the engine type and the extent of methane slip. (For more information, see Figure 9 in Appendix A)

The environmental benefits created by LNG bunkering and the uptake of LNG as marine fuel can be further enhanced with development of bio-LNG, which can reduce GHG emissions of over 70%, by blending LNG with biogas, since the chemical composition of LNG and biogas are very similar. While the development of bio-LNG is still in pilot stage and it is expected to take years to be fully commercialised, it is a sound investment now to develop LNG bunkering in Hong Kong to lock in immediate environmental benefits, with the prospect of additional benefits coming from future clean fuel options such as bio-LNG and synthetic LNG.

2.4 Potential opportunity cost for Hong Kong in the absence of LNG bunkering

In the absence of LNG bunkering, Hong Kong will suffer and lose its edge over competing ports as an international maritime hub. Its position as one of the world's top bunkering ports is also under threat. Since the global pandemic and with the imposed strict crew change requirements and quarantine restrictions, Hong Kong's bunker sales plunged by 30% to 40% in 2020, shrinking from over 500,000 mt per month pre-COVID-19 to just about 400,000 mt per month in recent months[28]. Some vessels are skipping Hong Kong and refuelling at other ports such as Shenzhen, Kaohsiung and Zhoushan. There is no guarantee that the ships will come back when the restrictions are relaxed, for example the port of Zhoushan is expanding its bunker sales with lower bunker fuel prices and the port of Yantian in Shenzhen started offering bonded fuel oil to ocean-going vessels in June 2021. Even Singapore, the world's largest bunkering port, is feeling the competition. Inaction in LNG bunkering while other competing ports are moving ahead will push Hong Kong further down the pecking order.

Another important aspect to consider is the health cost associated with air pollution induced by emissions from ships. The Hedley Environmental Index[29] developed by the University of Hong Kong School of Public Health estimated that in 2017, air pollution was directly related to more than 1,800 cases of premature death, 126,000 additional hospital bed days, and a cumulative economic loss of more than HK$22 billion locally. As the major source of air pollution in Hong Kong, ships contributed significantly to the external cost of air pollution. Without LNG bunkering,

[28] https://www.spglobal.com/platts/en/market-insights/latest-news/shipping/012621-hong-kongs-bunker-sales-pain-in-2020-reflects-zhoushans-gain
[29] http://hedleyindex.hku.hk/outcome_cost

ships would continue to burn fuels that emit high concentrations of NO_X and PM, impacting public health, especially in the communities closest to the port facilities.

Hong Kong has recently pledged to achieve carbon neutrality before 2050. With little local energy resources available, Hong Kong must import most of its energy. To decarbonise Hong Kong's fuel mix, coal will be phased out and natural gas can act as a promising interim solution. Relating to this, the Council for Sustainable Development not only suggested LNG as a market-ready transition fuel for Hong Kong, but also recommended the planning and construction of infrastructure required to supply low- or zero-carbon fuel to international shipping and aviation industries, to preserve and strengthen the status of Hong Kong as a key international port and aviation hub. Failure to provide these infrastructures in a timely manner will dent Hong Kong's ambition to become carbon neutral.

3 | The Prospect of LNG Bunkering in Hong Kong

3.1 The LNG value chain

In general, the LNG value chain can be divided into six parts: gas production, liquefaction, shipping, storage, regasification and reloading, and distribution for downstream use (Figure 4).

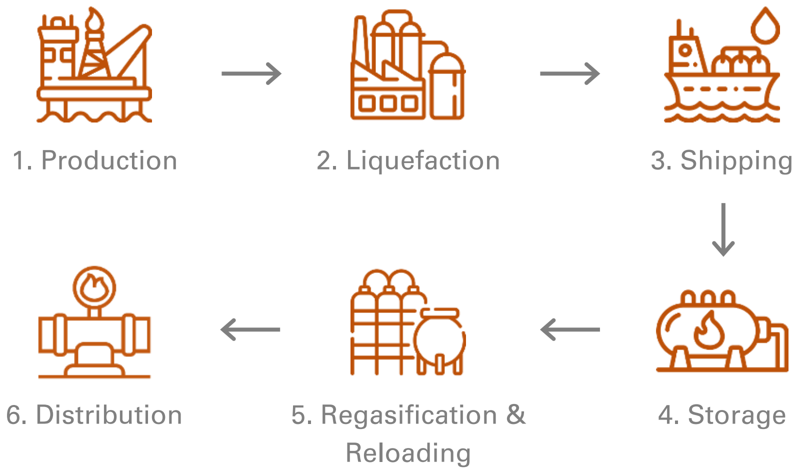

Figure 4. A typical LNG value chain

In the local context, since LNG will be imported as a product fuel, Hong Kong is not involved in upstream production, liquefaction, and the shipping of LNG, and regasification is only required for some downstream natural gas uses, such as power generation. Therefore, the focus for LNG bunkering in Hong Kong will be on unloading, storage, reload onto LNG bunker vessels, and distribution, which will be further explained in the following sections.

3.2 LNG infrastructure in Hong Kong

At present, Hong Kong receives natural gas through three subsea pipelines: one from Dachan Island in Shenzhen to Black Point Power Station as part of the larger Second West-East Pipeline Project; one from Yacheng gas field in the South China Sea, 780 km in length; and the last one from Shenzhen's Dapeng LNG receiving terminal to Lamma Island Power Station and the Towngas Tai Po Plant. However, the situation will soon change.

In 2018, CLP Power Hong Kong Limited and The Hongkong Electric Company, Limited began the development and construction of an offshore LNG receiving terminal in the southern waters of Hong Kong. The project includes a floating storage and regasification unit (FSRU) vessel, a double berth jetty with mooring facilities for the FSRU vessel and LNG carriers, as well as pipelines for the transfer of regasified LNG to power generation facilities. (Figure 5) The terminal is expected to be completed in 2022. Although the terminal is primarily planned for the supply of natural gas for power generation, it can extend to supply LNG to other end-users such as the shipping sector[30] to further support government policy on clean air and decarbonisation. With the main physical infrastructure already in construction, Hong Kong will soon have ready access to cost-competitive gas supplies globally, putting the city in a great position to promote and facilitate the use of LNG as marine fuel.

[30] It can be done via quicker drawdown and resupply based on the planned capacity, rather than to invest in additional capacity.

Figure 5. The Hong Kong offshore LNG terminal

3.3 Distribution of LNG for downstream use

Ports can typically select one of the following LNG supply options, depending on the inherent terminal layouts and customer vessel sizes: (a) truck-to-ship; (b) shore-to-ship; or (c) ship-to-ship[31]. Truck-to-ship bunkering is the most adopted option for inland vessels, but trucks have limited capacity and a lower flow rate. Therefore, it would take longer time for large-sized LNG fuelled vessels to be bunkered through a truck-to-ship process. This option would not be ideal for a busy port like Hong Kong with heavy marine traffic and limited land space in the port. Furthermore, the offshore LNG terminal under construction does not directly support truck-to-ship bunkering, as LNG would first have to land on an onshore spot in Hong Kong. Similarly, shore-to-ship operations require permanent onshore LNG storage facilities, which has not been planned in Hong Kong, and would be difficult due to the scarcity of available land. On the other hand, ship-to-ship bunkering offers most flexibility to Hong Kong in terms of capacity, bunkering location, and land requirements. It is also becoming popular in other ports like Singapore. With ship-to-ship bunkering, vessels in port can safely handle cargoes and refuel at the same time (also known as Simultaneous Operations or SIMOPS). As of the end of 2020, there were already over hundreds of ship-to-ship bunkering operations and SIMOPS with LNG bunkering worldwide. SIMOPS is particularly important to the cargo trade as operational efficiency can be improved through reduced time spent in port, allowing ships to make extra journeys for additional revenue.

[31] https://sustainableworldports.org/clean-marine-fuels/lng-bunkering/ports/lng-bunker-infrastructure/

3.4 Existing policies and regulations

LNG has a strong safety record across the world, but the handling of LNG requires specific skills and training capabilities, as well as careful handling as it must be stored at -162°C. High-precision operations and handling, clearly established operational rules and regulations, safety procedures and guidelines, suitable staff training and certification are the key elements to operate any LNG bunker operations safely.

Currently, there are no regulations or guidelines from the Hong Kong Government regarding the use and handling of LNG. However, the construction of gas-related infrastructures and gas carriers are regulated under the *Gas Safety Ordinance Cap. 51* [32] and *Merchant Shipping (Safety) (Gas Carriers) Regulations Cap. 369Z* [33], respectively. Requirements for personnel serving on liquified gas tankers are outlined in the *Merchant Shipping (Seafarers) (Tankers) Regulation Cap. 478AG* [34].

The Electrical and Mechanical Services Department (EMSD) is responsible for the assessment approval and monitoring of natural gas supply facilities and pipelines, while the Marine Department is responsible for matters related to shipping and navigation. This divergence of roles may cause inefficiencies, delayed responses and lengthy approval processes without strong policy and regulatory support at the heart of the government's decarbonisation strategy, as has been the case in Singapore.

Acknowledging LNG bunkering as a potential economic opportunity for Hong Kong, the Hong Kong Government and other key stakeholders working in concerted effort can leverage the existing global LNG bunkering best practices and regulations, and make a swift move to draw up a suitable regulatory framework for Hong Kong. Examples of international and Chinese standards and best practices will be discussed in the following sections.

3.5 International and Chinese standards and regulations

Globally, the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* [35] (IGC Code) regulates LNG carriers and outlines the design and construction standards of such vessels to minimise the risks involved. The *International Code of Safety for Ships using Gases or other Low-flashpoint Fuels* [36] (IGF Code) that entered into force in 2017 includes a section on bunkering, aiming to regulate bunkering systems on board to ensure the safety of such operation. Mandatory requirements for the "arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels", including LNG, is

[32] https://www.elegislation.gov.hk/hk/cap51

[33] https://www.elegislation.gov.hk/hk/cap369Z

[34] https://www.elegislation.gov.hk/hk/cap478AG

[35] https://www.imo.org/en/OurWork/Safety/Pages/IGC-Code.aspx

[36] https://www.imo.org/en/OurWork/Safety/Pages/IGF-Code.aspx

also outlined in the regulation. Regulation V/3 and Section A-V/3 of the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers* [37] (STCW Convention) further sets out minimum requirements for the familiarisation and training of different levels of seafarers on ships that are subject to the IGF Code. Furthermore, Classification Societies (e.g. DNV, Lloyd's Register, Bureau Veritas) also published guidelines with statutory requirements incorporated.

In China, the adoption of LNG is encouraged through policies and the establishment of regulations. The construction of LNG terminals, especially in coastal areas, was emphasised in the *13th Five-Year Plan for Energy Development* [38] (能源發展"十三五"規劃) released in late 2016. In the *13th Five-Year Plan for Natural Gas Development* [39] (天然氣發展"十三五"規劃) in 2017, it was suggested that LNG terminals should be constructed in more polluted areas and areas with more stringent environmental regulations, and existing terminals should expand their handling capacities. The use of LNG in the marine sector and inland waters was promoted and pilot projects on LNG transport using both maritime and inland waterways (LNG 江海聯運) were set up. In August 2018, the Chinese Ministry of Transport released a *Consultation Document on Boosting the Use of Liquefied Natural Gas as Marine Fuel* [40] (關於深入推進水運行業應用液化天然氣的意見（徵求意見稿）) and called for opinions from relevant stakeholders. Key propositions in the document include the expansion of the current LNG bunkering network as well as the increase in application of LNG in the marine sector. Although the consultation document has not been formally republished as a policy document, it is clear that the mainland authorities are keen to promoting the use LNG as marine fuel.

In the regional context, the Guangdong Government has encouraged companies to construct LNG receiving terminals and storage facilities through the *Guangdong Government Promotion on Natural Gas Utilisation Implementation Plan* [41] (廣東省促進天然氣利用實施方案) in 2018. The provincial government also signed a *Cooperation Framework Agreement on LNG Retrofits on Domestic Vessels* [42] (廣東省內河船舶 LNG 動力改造項目合作框架協定) with two shipbuilding and energy companies in May 2020. According to the Agreement, the Guangdong government will complete 1,500 LNG retrofits and construct 19 LNG bunkering stations by 2024.

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[37] https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Convention.aspx

[38] (In Chinese only) https://policy.asiapacificenergy.org/sites/default/files/%E8%83%BD%E6%BA%90%E5%8F%91%E5%B1%95%E2%80%9C%E5%8D%81%E4%B8%89%E4%BA%94%E2%80%9D%E8%A7%84%E5%88%92pdf.pdf

[39] (In Chinese only) https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201706/W020191104624281237228.pdf

[40] (In Chinese only) http://xxgk.mot.gov.cn/2020/jigou/syj/202006/t20200623_3314592.html

[41] (In Chinese only) http://www.gd.gov.cn/zwgk/wjk/qbwj/yf/content/post_1053040.html

[42] (In Chinese only) http://www.gd.gov.cn/gdywdt/gdyw/content/post_3005846.html

The *Natural Gas Infrastructure Construction and Operation Administrative Measures* [43] (天然氣基礎設施建設與運營管理辦法) released in 2014 regulates the planning, construction, and operation of natural gas infrastructure, including LNG terminals and regasification units. The *Provisions on the Safety Management of Hazardous Goods at Ports* [44] (港口危險貨物安全管理規定) covers the licensing and operational requirements of port authorities on the handling of hazardous goods, of which LNG is included. The *Administrative Regulations on Dangerous Goods Transported by Ship*[45] (船舶載運危險貨物安全監督管理規定) published in 2018 specifies protocols and requirements of LNG terminals and LNG vessels in Articles 27, 32 - 38. In February 2020, The Chinese Marine Safety Administration released the *LNG Bunkering Safety Administrative Measures* [46] (水上液化天然氣加注作業安全監督管理辦法) which would be effective for five years. The regulation describes the monitoring authority of LNG bunkering operations and spells out operators' obligations on licensing, training of seafarers, reporting, safety precautions and maintenance. Whilst the above list of codes and regulations may seem extensive and detailed, they are useful and practical references for Hong Kong in the knowledge that not all the guidelines and regulations would have to start from scratch, and Hong Kong can ride on existing standards and best practices and adapt.

3.6 Policy and regulatory enablers that drive LNG bunkering adoption

3.6.1 Singapore

The Singapore Government has set out various policies to promote LNG-fuelled vessels and LNG bunkering since 2015. The Maritime and Port Authority of Singapore (MPA) has been granting LNG bunkering supplier licences since 2016.

In 2017, Singapore launched a 3-year LNG Bunkering Pilot Programme[47] to encourage LNG bunkering for both ocean-going and domestic vessels. The MPA supported the building of LNG-fuelled vessels by establishing a S$12 million co-funding programme. In 2017, MPA announced a 5-year waiver of craft dues for new LNG-fuelled harbour craft and a 10% port dues concession for ocean-going vessels that are serviced by such LNG-fuelled harbour craft during their port stay. These incentives were further extended for another five years from 2020.

Furthermore, the Singapore authorities also actively encourage fuel transition to LNG. Singapore-flagged ships that use LNG as primary fuel can enjoy a 75% reduction on the Initial Registration Fee and a 50% rebate on the Annual Tonnage Tax. Ocean-going vessels that exceed the existing

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[43] (In Chinese only) http://www.gov.cn/zhengce/2014-03/20/content_2642222.htm

[44] (In Chinese only) http://www.sdsiwei.net/uploads/soft/20171017/1-1G01G03414.pdf

[45] (In Chinese only) http://www.gd.gov.cn/zwgk/wjk/zcfgk/content/post_2720641.html

[46] (In Chinese only) https://www.sh.msa.gov.cn/hsfg/content.jspx?cid=9C29F0A27CF67912E0533A0820C68458

[47] https://www.mpa.gov.sg/web/portal/home/port-of-singapore/services/bunkering/lng-bunkering-pilot-programme

IMO EEDI and use LNG for both main and auxiliary engines can also enjoy a 25% reduction in port dues[48]. The incentives are all effective from 2020 to 2024.

To provide guidance to the relevant operators, the Technical Reference (TR) 56 for LNG Bunkering was developed to provide an approach to align national standards with the industry's standards on custody transfer, safety, procedural and personnel requirements for LNG bunkering operations. The MPA has also signed a memorandum of understanding with 10 other port authorities and government ministries to strengthen collaboration and information sharing related to LNG bunkering.

In short, Singapore took a gradual approach – from the initial promotion of truck-to-ship bunkering to build up knowledge and experience, to the development and adoption of a prescriptive national standard for LNG bunkering with strong government support.

3.6.2 European Union

In 2014, the European Union (EU) adopted the Directive 2014/94/EU on the deployment of alternative fuels infrastructure, which requires its 27 member states to develop national policy frameworks for alternative fuels and relevant infrastructure, as well as recommending the use of common technical specifications for recharging and refuelling stations. It introduces the mandatory provision of LNG at both maritime and inland ports along the Core Network of the Trans-European Transport Network (TEN-T) between 2025 and 2030. LNG is also required to be made available for heavy-duty vehicles along selected points of the TEN-T core network by 2025[49]. In 2018 the European Maritime Safety Agency (EMSA) has launched the *Guidance on LNG Bunkering to Port Authorities and Administration* to provide port authorities with necessary information regarding LNG bunkering operations, also outlining best practices.

The EU has various financing programmes to promote the use of LNG in the marine sector. To support the construction of LNG bunkering facilities, the TEN-T Programme[50] has funded governments of EU member states to develop national policies on the use of LNG in both marine and road transport, conduct feasibility studies on and subsidise the construction of LNG bunkering infrastructure. For instance, the Poseidon Med II LNG Bunkering Project[51], a key EU project to promote LNG as marine fuel and develop a significant infrastructure network across the LNG value chain in the Eastern Mediterranean and Adriatic Sea, was co-financed by the TEN-T Programme.

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[48] https://www.mpa.gov.sg/web/wcm/connect/www/e9bb09e0-a605-4ec5-a499-539bfe54ce92/MSGI+Enhanced+%28print%29.pdf?MOD=AJPERES

[49] https://www.eafo.eu/alternative-fuels/overview

[50] https://ec.europa.eu/inea/ten-t

[51] https://www.poseidonmedii.eu/

The EU-initiative Connecting Europe Facility for Transport also supports investments in building new LNG infrastructure in Europe or upgrading the existing facilities[52], such as the €11 million fund granted to Titan LNG to add three new bunker barges for supporting the upcoming bio-LNG services[53]. The €3 billion Green Shipping Guarantee Programme of the European Investment Bank further finances shipbuilding projects, which include new LNG vessels and the conversion and LNG retrofitting of vessels[54]. LNG bunkering is also supported through national policy initiatives. For example, the Spanish "LNGHIVE2" initiative sets out plans for LNG retrofits; the construction of LNG stations, regasification plants, and bunkering barges; the introduction of LNG in green transport corridors; as well as the installation of multi-truck to ship system to enhance LNG bunkering efficiency[55].

Along with the EU initiatives, several EU member states are offering their own financial assistance to promote the adoption of LNG as a cleaner marine fuel. For instance, since 2019, France has been offering 30% capital allowance for investments in ships powered by LNG. Additionally, Germany has committed to offer an allowance from its €1 billion crisis aid for new LNG fuelled ships and for the conversion of ocean-going vessels to LNG until 2022.

Looking ahead, the use of bio-LNG has begun to be considered in the EU. Industry groups such as the European Biogas Association, Gas Infrastructure Europe, NGVA Europe and SEA-LNG issued a joint paper[56] and called on the EU member states in future to also recognise bio-LNG as a marine fuel to enable decarbonisation of the heavy-duty transport and shipping sector and help the EU achieve its carbon neutrality target by 2050.

[52] https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport

[53] https://titan-lng.com/titan-lngs-ambitious-bio-lng-breakthrough-project-receives-eu-funding/

[54] https://www.eib.org/en/projects/pipelines/all/20150334

[55] https://safety4sea.com/the-european-commission-supports-lng-bunkering-in-spanish-ports/

[56] https://sea-lng.org/wp-content/uploads/2020/11/BioLNG-in-Transport_Making-Climate-Neutrality-a-Reality_20.11.2020.pdf

4 | Recommendations for Hong Kong

4.1 Proposed LNG value chain

Figure 6 below illustrates a simplified natural gas value chain in Hong Kong that incorporates the plan to develop LNG bunkering, utilising the LNG receiving terminal in Hong Kong waters under currently construction. The top of the diagram shows the existing gas infrastructure that supports power generation and energy production at Black Point, Lamma Island and Tai Po.

With the completion of the offshore LNG receiving terminal to the south of Lantau Island, the value chain in Hong Kong will be expanded, as shown in the middle of Figure 6, to include the direct supply of LNG, mainly for power generation but also essential for the prospective bunkering market. With the terminal in place, Hong Kong will have access to the global LNG market with reliable supply at competitive prices. The new infrastructure would allow the importation of LNG delivered by an LNG carrier to be stored onboard the FSRU vessel at the offshore terminal, regasified using the vaporisers onboard of the FSRU vessel, and transported via pipelines to Black Point Power Station and Lamma Power Station.

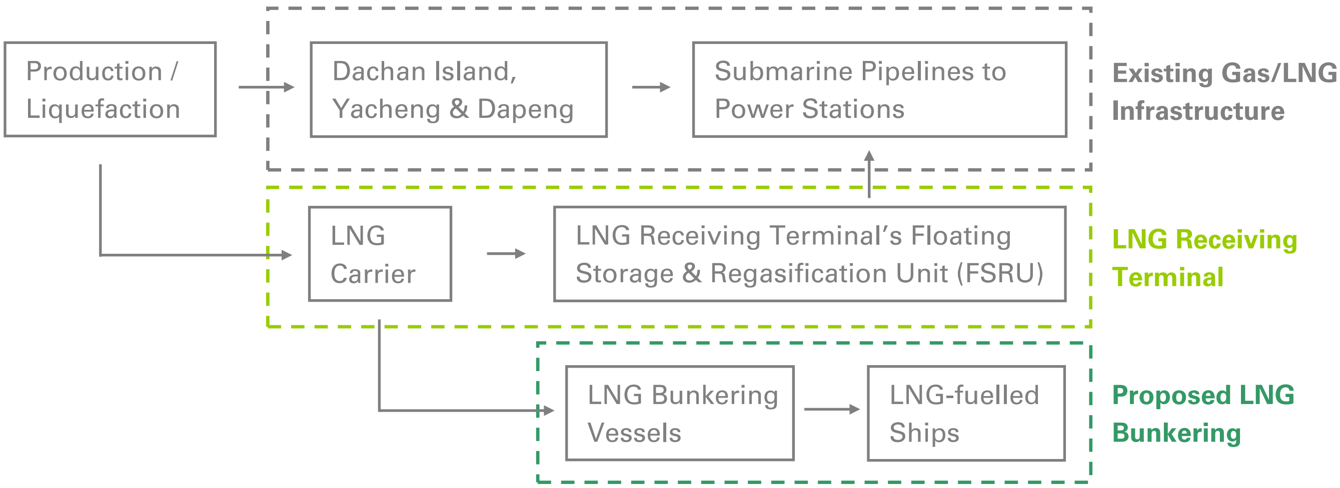


Figure 6. Simplified natural gas value chain in Hong Kong

To complete the last mile of the LNG bunkering value chain, LNG will be made available to LNG-fuelled ships with the support of LNG bunkering vessels. As noted in Section 3.3, ship-to-ship bunkering would be the preferred option in Hong Kong given the local physical and operational constraints.

Similar to conventional ship-to-ship bunkering operations of fuel oil, bunkering arrangements, marine traffic impact assessments, and operational procedures will need to be considered. Detailed options and arrangements such as the bunkering frequency, location, and the schedule to supply LNG to bunkering vessels from the FRSU, would also have to be considered. The potential additional impacts to the marine ecosystem, existing shipping routes, and marine safety may require further assessment.

Operational procedures are also crucial to the safety and efficiency of LNG bunkering operations, although these are already well-versed overseas. Such considerations are explained in detail in the next section with reference to existing international and regional standards and regulations.

4.2 Proposed regulatory framework for Hong Kong

It is envisaged that the regulatory framework for LNG bunkering in Hong Kong should cover the following aspects: (a) licensing, (b) safety, (c) personnel competence, (d) environment and sustainability, and (e) simultaneous operations.

Referenced standard(s)

4.2.1 Licensing considerations

Under the Gas Safety (Registration of Gas Supply Companies) Regulations Cap. 51E[57], companies who manufacture, supply, or import LNG must submit their application to become a registered gas supply company (RGSC) approved by EMSD.

RGSCs have a self-regulating duty to ensure the health and safety of workers and the public from the undue risks from gas. In the future, LNG bunker sellers would need to hold RGSCs in Hong Kong to sell or bunker marine LNG.

Apart from the need to apply as an RGSC, other licensing considerations regarding LNG bunkering services should also be assessed. For example, the Port of Rotterdam has a comprehensive policy that assesses ship safety, operational safety, SIMOPS, nautical safety, terminal preparation, and external safety and compliance before issuing ship-to-ship bunkering licenses to applicants.

The International Association of Ports and Harbors (IAPH)'s World Ports Sustainability Program also released a set of checklists[58] for different LNG bunkering scenarios with the aim to harmonise bunker checklists for ports around the world. The ship-to-ship bunkering checklist, for instance, covers the planning, SIMOPS, and pre- and post- transfer stages of LNG bunkering operations. The IAPH checklist is also referred in the Port of Rotterdam's licensing procedure, and such conditions could be readily adapted for use in Hong Kong.

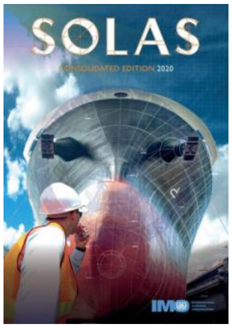
4.2.2 Procedures and safety guidelines

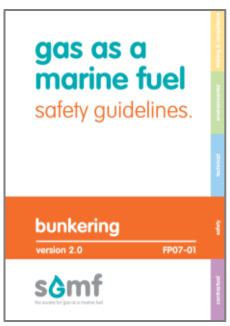
Although the mishandling of LNG can lead to health and safety concerns, the LNG industry has an extremely good safety record and LNG carriers have sailed over 100 million miles without fatality or a

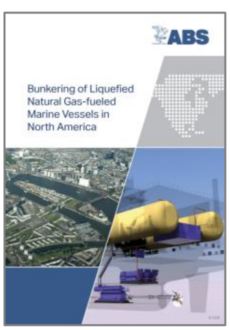
[57] https://www.elegislation.gov.hk/hk/cap51E

[58] https://sustainableworldports.org/clean-marine-fuels/lng-bunkering/bunker-checklists/#sts

Referenced standard(s)







major incident [59], highlighting the importance of robust design standards, good operational safety procedures and the maintenance of safety equipment.

International Convention for the Safety of Life at Sea [60] (SOLAS), an international maritime treaty, sets out the minimum standards for the construction, equipment, and operations of ships. The IMO also provides mandatory criteria for the design, usage, equipment and system arrangement and installation for vessels operating with LNG through the IGC and IGF Codes.

There are numerous standards [61] issued by the International Organisation for Standardisation (ISO) related to the use of LNG – for instance *ISO/TS 18683:2015 Guidelines for systems and installations for supply of LNG as fuel to ships* is a technical guidance to ensure the safe and efficient use and transfer of LNG as a fuel; *ISO/TS 16901:2015 Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface* outlines a risk assessment methodology; and *ISO 20519:2017 Ships and marine technology - Specification for bunkering of LNG fuelled vessels* was developed to support the IMO's IGF Code and standardise LNG bunkering operations internationally. The standard covers transfer systems, operational procedures, delivery note requirements and personnel training and qualifications.

The Society for Gas as a Marine Fuel (SGMF)[62] published their *Safety Guidelines – Bunkering Version 2.0* in 2017, as a revision to the original version in 2014, to provide comprehensive guidance for LNG bunkering operations. The next revision is due towards the end of 2021 to incorporate operational experience and feedback from the growing industry.

On the regional level, classification societies and national maritime safety authorities have also published various guidelines on LNG bunkering operation and safety standards, such as the American Bureau of Shipping (ABS)'s *Bunkering of Liquefied Natural Gas-fuelled Marine Vessels in North America* [63], European Maritime

[59] https://www.nbcnews.com/id/wbna18556688

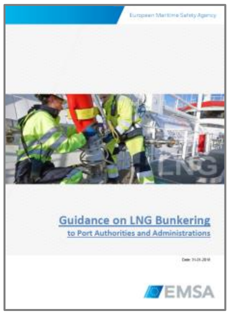
[60] https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

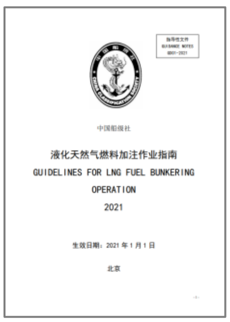
[61] https://giignl.org/system/files/iso_lng_standards_mapping_oct2018.pdf

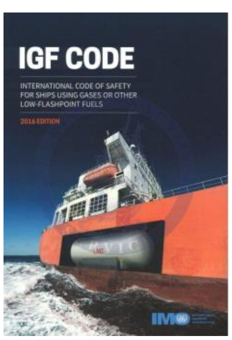
[62] https://www.sgmf.info/

[63] https://ww2.eagle.org/content/dam/eagle/publications/reference-report/LNG%20Bunkering.pdf

Referenced standard(s)







Safety Agency (EMSA)'s *Guidance on LNG Bunkering to Port Authorities and Administrations*[64], Singapore's TR56, Chinese Classification Society (CCS)'s *Guidelines for LNG Fuel Bunkering Operations*[65] (液化天然氣燃料加注作業指南), and China Maritime Safety Administration's *Regulations on Safety Supervision and Management of Marine LNG Bunkering Operations*[66] (水上液化天然氣加注作業安全監督管理辦法) and *Safety Regulation for Marine Refuelling Operations for LNG Fuel*[67] (液化天然氣燃料水上加注作業安全規程). Although not entirely aligned, these standards generally covered the following areas:

- Control zones
- Personnel qualifications
- Personal/Structural safety and protection
- Risk assessment
- Emergency response and management
- SIMOPS

Again, these references provide a ready source of policies and procedures which could easily be considered in developing appropriate regulations for Hong Kong.

4.2.3 Personnel competency considerations

At present, there are several international guidelines that provide operational and training requirements for seafarers using gas or low-flashpoint fuels, including LNG. In terms of training, the IGF Code recommended three levels of training for workers: (a) basic training for the basic safety crew; (b) supplementary training for deck officers; and (c) supplementary training for engineering officers. According to the IGF Code, basic training is designed for seafarers responsible for designated safety duties, whereas supplementary and advanced training is designed for masters, engineering officers, and all personnel with immediate responsibility for the care and use of fuels and fuel systems.

Apart from the IGF Code, the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers* (STCW)

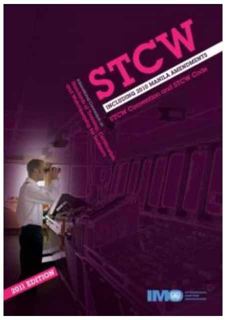
[64] http://emsa.europa.eu/hns-pollution/items.html?cid=280&id=3207

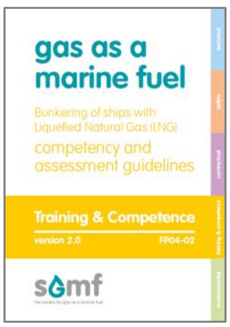
[65] (In Chinese only) https://www.ccs.org.cn/ccswz/articleDetail?id=202012180330229072

[66] (In Chinese only) https://www.sh.msa.gov.cn/hsfg/content.jspx?cid=9C29F0A27CF67912E0533A0820C68458

[67] (In Chinese only) http://xxgk.mot.gov.cn/jigou/kjs/202004/t20200430_3370241.html

Referenced standard(s)





sets out the minimum requirements for seafarers, and is also widely adopted and referenced when governments develop their local policies and regulations. The STCW Code, made up of mandatory and recommendary parts, also provides guidance on special training requirements for personnel on bunker vessels carrying liquefied gas cargoes:

- Knowledge of the ship's rules and regulations
- Health hazards and precautions to be taken
- Fire prevention and firefighting
- Pollution prevention
- Safety equipment and its use
- Emergency procedures
- Dangers and precautions related to handling and storage of cargoes at cryogenic temperatures

Apart from minimum requirements by the IMO, SGMF developed two sets of competency and assessment guidelines for operating and bunkering ships with LNG. These guidelines laid out recommended training modules, fundamental knowledge, assessment frameworks, and roles and responsibilities for crew. Building on SGMF's guidelines, Singapore's TR56 also has a dedicated part[68] on personnel competency requirements.

4.2.4 Environmental sustainability considerations

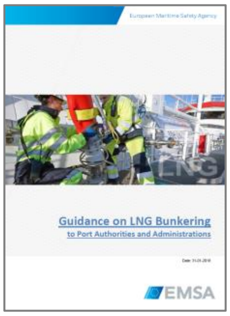
While LNG is a low emission fuel with greatly reduced air pollutant emissions and lower GHG emissions than conventional marine fuels (see Section 2.3), the amount of methane released along the entire value chain would significantly affect LNG's GHG emission reduction potential. Therefore, it is crucial for ports and operators to put in place rigorous measures that prevent methane slip during the bunkering process in order to control the overall GHG emissions, for example restricting the ventilation of boiled-off gas under non-emergency scenarios.

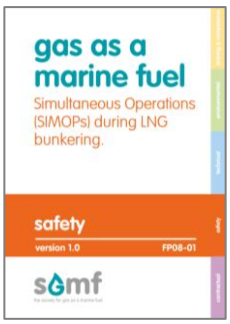
The World Bank Group has published a set of Environmental, Health, and Safety (EHS) Guidelines[69] specifically for LNG facilities (including FSRUs), mandated by major lenders for global LNG projects they finance to follow. The guidelines address a spectrum of potential

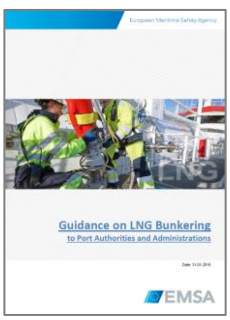
[68] https://www.singaporestandardseshop.sg/Product/SSPdtDetail/1617d6d9-b560-4ee6-a528-d24782d1fe65

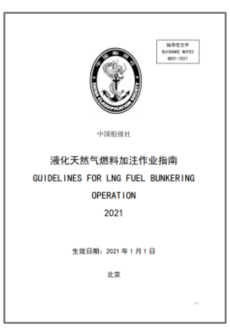
[69] https://www.ifc.org/wps/wcm/connect/ab72db72-736a-43e7-8c81-f2d749ec3ad1/20170406-FINAL+LNG+EHS+Guideline_April+2017.pdf?MOD=AJPERES&CVID=lJuCgVs

Referenced standard(s)









environmental issues that may be faced by LNG facilities, including methane release, emissions and effluents, and monitoring.

For the bunkering side, the EMSA has devoted a section in their Guidance on methane release mitigation. It is stressed that the port authorities and administrations have a major role in ensuring bunker facility operators mitigate relevant risks through boil-off gas management, facility design, operation, maintenance, compatibility assessment, and proper purging and inerting procedures. Environmental management systems are also recommended to be adopted as best practice by bunker facility operators. The Guidance has also suggested mitigation measures for both LNG bunker vessels and barges (See Figure 10 & Figure 11 in Appendix B).

For vessels receiving LNG as a bunker fuel, complying with relevant sections in the IGF Code (for example, the bunkering system is arranged that no gas is discharged to the atmosphere during the refuelling) during the bunkering process should suffice in preventing menthane release.

4.2.5 Simultaneous operations guidelines (SIMOPS)

SIMOPS refers to two or more operations occurring in the same location at the same time that may interact with each other. In the context of LNG bunkering, a typical example of a SIMOP is the loading and unloading of passengers/cargoes while an LNG-fuelled vessel is being bunkered. As additional activities can lead to different parties being exposed to additional risks, SIMOPS need to be carefully planned and executed.

SGMF published a set of guidelines for *SIMOPS during LNG Bunkering* in 2018 that included detailed risk management guidelines in stages for operations during bunkering, as well as port planning and ship design considerations. EMSA's Guidance has a dedicated section on SIMOPS, providing guidance on safety and operational issues, as well as risk identification and assessment best practices, which could serve as a good model for Hong Kong. CCS guidelines also recommend a quantitative risk assessment before carrying out SIMOPS.

Referenced standard(s)

4.2.6 Other considerations based on global regulatory frameworks

Maritime security

The International Ship and Port Facility Security (ISPS) Code developed by IMO was agreed in December 2002 to align international standards on maritime security against terrorism and piracy and took effect starting in July 2004. The code aims to establish an international framework for governments, shipping companies, and ports to collaborate on preventing and detecting security incidents, as well as to ensure clear and timely communications and information exchange between relevant parties.

The code sets out mandatory requirements for ships and ports to undergo security assessments, develop security plans, and assign security officers to monitor and control access of restricted areas, people and cargo activities and ensure security communications.

Ship design standards in China

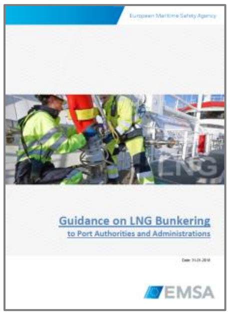
In addition to the IMO's IGF and IGC Codes, there are also design standards for LNG bunkering infrastructure in China. This includes mandatory national standards like *GB51156-2015 Code for Design of LNG Receiving Terminal* (液化天然氣接收站工程設計規範), and *GB/T 51312-2018 Standard for Design of LNG Bunkering Station for Vessel* (船舶液化天然氣加注站設計標準), as well as vessel design standards from CCS such as *Standard for LNG Bunkering Vessels* (液化天然氣燃料加注船舶規範) and *Standard for LNG Bunkering Pontoons* (液化天然氣燃料加注躉船規範).

Port governance in Europe

As ports may not be entirely familiar with the use of LNG as a fuel, the EMSA Guidance has listed out good practice guides and governance principle for port authorities and administrations.

Figure 7 below outlines the roles and interactions between the three main parties involved in LNG bunkering operations – in which the Guidance mentioned that safety, transparency, and the

Referenced standard(s)



independence between the three parties should always be observed to avoid a conflict of interest.

Other good practice examples for port authorities include: provide leadership, maintain administrative frameworks, define relevant standards, minimum requirements and scope of responsibility for operators, and develop platforms for experience sharing and learning between operators, ports and other stakeholders, as LNG bunkering is still a relatively new port service.

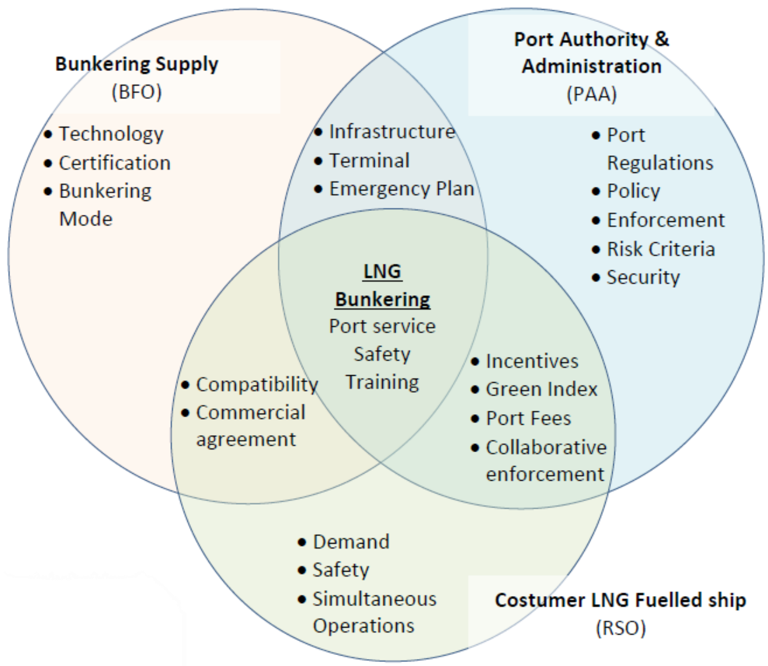


Figure 7. Roles and interactions between stakeholders

Source: EMSA Guidance on LNG Bunkering to Port Authorities/Administrations, Figure 5.1

The above examples show that there is an abundance of internationally recognised and proven standards and guidelines that cover different aspects of LNG bunkering operations, which can easily be considered in developing relevant standards for local application. Hong Kong can build the regulatory framework around these examples to harmonise its standards and procedures with ports across the globe and avoid the need to reinvent the wheel. Consistency with international standards and practices is also welcome by the shipping industry and LNG bunkering operators.

4.3 A high-level roadmap for LNG bunkering in Hong Kong

In the new *Clean Air Plan for Hong Kong 2035*, the Government indicated its intention to explore the use of the offshore LNG terminal as a bunkering facility for vessels, including the planning for LNG bunkering areas and the formulation of technical and safety standards and requirements for offshore LNG bunkering. To implement this clear policy direction, BEC recommends a step-by-step approach to plan and develop an LNG bunkering ecosystem in Hong Kong (Figure 8).

The Government and relevant industry players can lay the groundwork by conducting a preliminary study to identify the optimal site locations, and safety and operational arrangements for ship-to-ship bunkering in Hong Kong. While the LNG receiving terminal is still under construction, the Government can start engaging with the private sector and developing licensing requirements and related guidelines and regulations for LNG bunkering.

Meanwhile, the Government can also introduce policies that will incentivise and attract LNG-fuelled ships to berth and bunker in Hong Kong, for example, waiving or reducing port fees for LNG-fuelled ships.

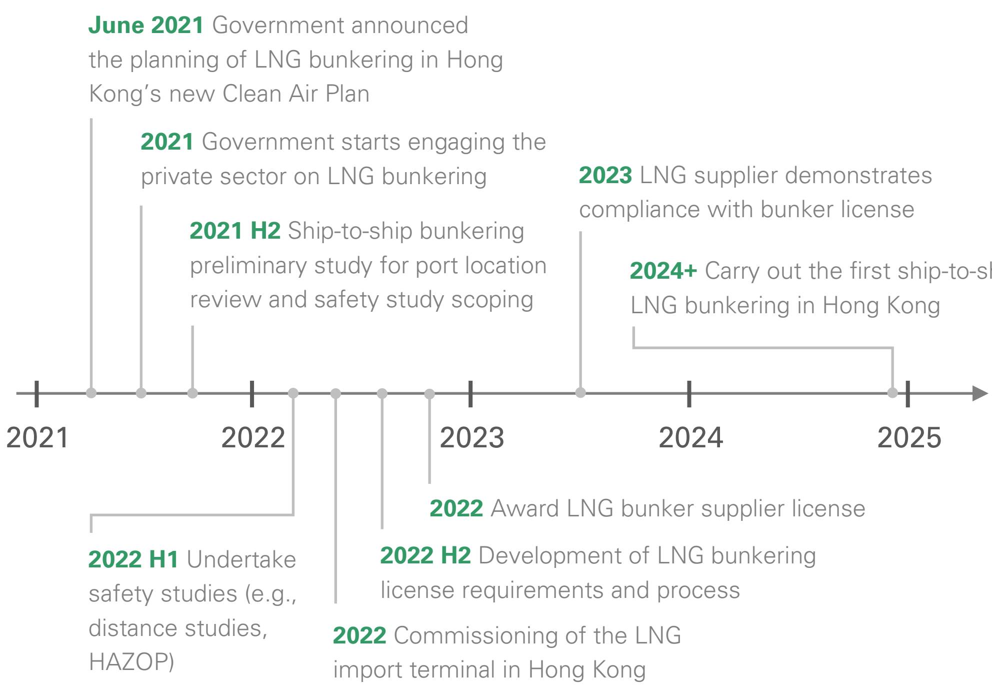


Figure 8. High-level roadmap for LNG bunkering in Hong Kong

4.4 Conclusions

LNG is a proven alternative marine fuel that is safe, mature, and available. There are internationally recognised standards and guidelines that the Hong Kong Government should review and adopt for the local use of LNG as a bunker fuel. The provision of safety standards and other regulatory guidelines are crucial for the development of LNG bunkering in Hong Kong, and these works should begin as soon as possible.

It is acknowledged that LNG is not *the* zero-carbon solution for the shipping sector, but it is the most mature alternative available at scale today. Early transition to LNG would bring immediate and significant air quality improvement benefits that would accumulate over time, especially to workers and residents near the port, as opposed to waiting for the perfect zero-emission fuels to become mature.

In terms of GHG reduction benefits, existing engine technologies are already achieving lower well-to-wake carbon emissions with LNG. Looking upstream, signatories of the Methane Guiding Principles are committed to reduce methane emissions across the gas supply chain, and engine manufacturers are improving LNG engine designs to reduce methane emissions downstream.

With these latest technical and policy developments, it is clear that the early adoption of LNG bunkering will be beneficial to Hong Kong – considering the economic benefits of Hong Kong being a competitive port offering an emerging fuel option to ships, and the environmental benefits associated with LNG. Most leading bunkering ports of the world have already developed the infrastructure and policy support for LNG bunkering to attract more ships to their ports. Given the imminent commissioning of the LNG receiving terminal and the strong support from the shipping industry, Hong Kong should move quickly to offer LNG to ships.

Glossary

CCS	Chinese Classification Society
CO_2	Carbon Dioxide
ECA	Emission Control Area
EEDI	Efficiency Design Index
EMSA	European Maritime Safety Agency
EMSD	Electrical and Mechanical Services Department
EU	European Union
FSRU	Floating Storage and Regasification Unit
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HAZOP	Hazard and Operability Study
HFO	Heavy Fuel Oil
IAPH	International Authority of Ports and Harbors
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF	The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels
IMO	International Maritime Organisation
ISO	International Organization for Standardization
ISPS	International Ship and Port Facility Security
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MGO	Marine Gas Oil
MPA	Maritime and Port Authority of Singapore
mt	Metric Tonnes
NO_X	Nitrogen Oxides
OEM	Original Equipment Manufacturer
PM	Particulate Matter
RGSC	Registered Gas Supply Company
SGMF	Society for Gas as a Marine Fuel
SIMOPS	Simultaneous Operations
SOLAS	Safety of Life at Sea
STCW	Standards of Training, Certification and Watchkeeping for Seafarers
TEN-T	Trans European Transport Network
TR	Technical Reference
WtW	Well-to-wake

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Appendix A

In general, diesel cycle engines have less methane slip than otto cycle engines. Thinkstep's Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel[70] published in 2020 highlighted that the well-to-wake (WtW) GHG emission reductions for 2 stroke engines compared to HFO and MGO and range from 14% to 21%. Methane slip is assumed at 0.14g/kWh for the 2-stroke diesel dual fuel engine and 2.1 g/kWh for the 2-stroke Otto dual fuel engine. While for 4-stroke engines, the WtW GHG emission reductions range from 4% to 15%.

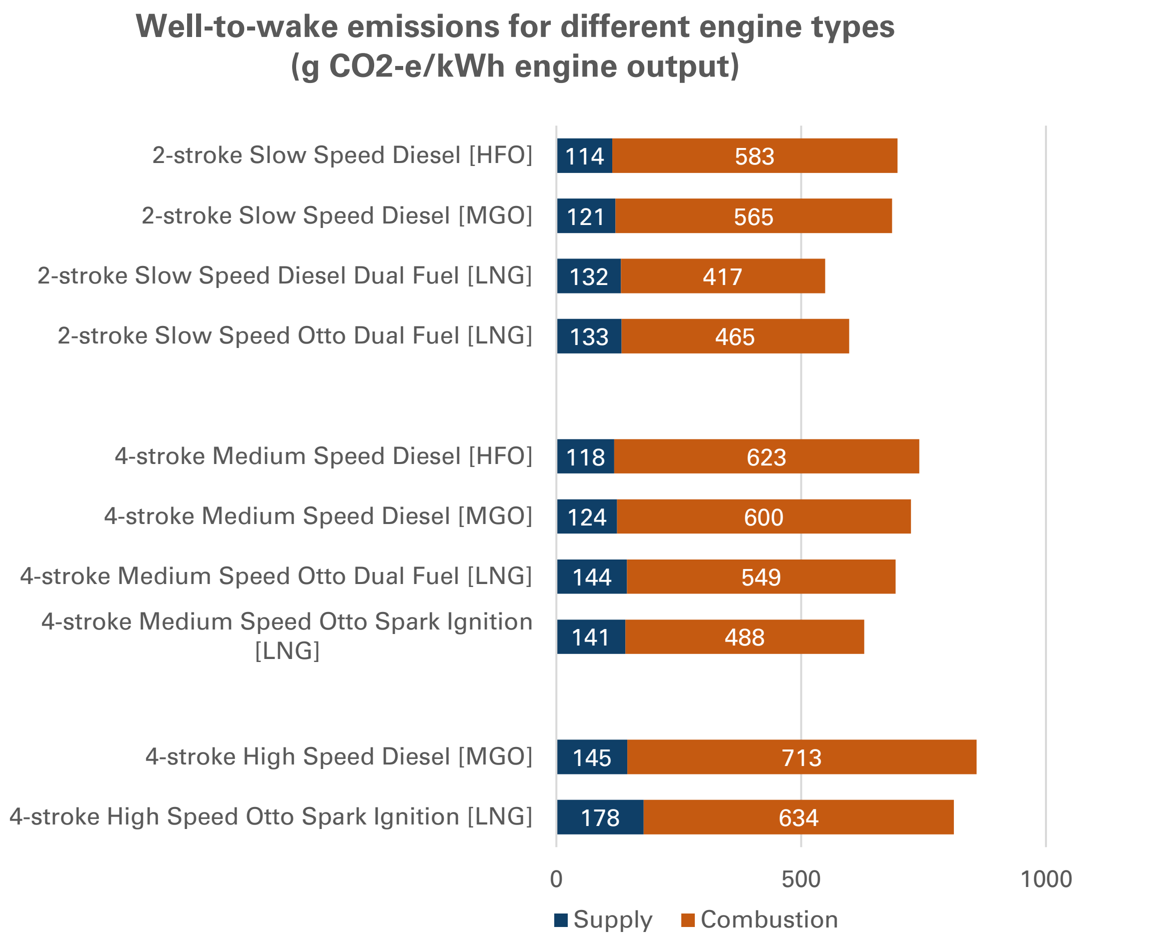

Figure 9. Well-to-wake emissions for different engine types

Source: Life Cycle GHG Emission Study on the Use of LNG as Marine Fuel, Thinkstep

[70] https://3gry456jeet9ifa41gtbwy7a-wpengine.netdna-ssl.com/assets/ts-SEA-LNG-and-SGMF_GHG-Analysis-of-LNG_Full_Report_v1.0.pdf

Appendix B

		Bunkering Hoses Connection	Inerting Ox	Purge & Cool-down with LNG Vapour	START Bunkering Transfer	Top-Up	STOP Bunkering Transfer	Drain Bunkering lines	Inerting NG	Bunkering Hoses Disconnection
	Objective/Description	▪ Following preliminary checks (see section 12, bunkering hoses are connected. ▪ Main transfer hoses and vapour return hoses can be considered	▪ Inerting of bunkering lines to displace oxygen from inside of the bunkering line – to avoid formation of explosive atmosphere ▪ Inert Gas used	▪ Also known as Gassing-up, or gas filling. ▪ Can be done with vapour purge line or with small volumes of new LNG ▪ Allows thermal shock to be avoided	▪ With cold lines and tanks both bunkering/transfer sides at similar temperatures, the bunkering begins.	▪ As the receiving ship tank is filled and aproaching its full conditon the rate must be reduced and the pressure constantly monitored. ▪ Procedure to be agreed between BFO and RSO.	▪ Once ensure no LNG is in the bunkering lines transfer is stopped. ▪ ESD shall not be used to stop bunkering transfer	▪ Drainage of bunkering lines to allow all liquid LNG to be displaced out of the bunkering line into RSO tank. ▪ LNG to vaporize in the lines while the valves leading to the ship's fuel tank are left open	▪ Inert the LNG bunker lines to prevent a flammable gas mixture from accumulating in the pipes or hose. ▪ Nitrogen typically used ▪ Also known as "Purging"	▪ Bunkering hoses disconnected after confirmation of <2% methane in volume inside the bunkering lines.
When Procedure complete	Contents in the hose	Air	Inert Gas (nitrogen)	Warm LNG/ LNG Vapour	LNG liquid	LNG liquid	LNG vapour	LNG vapour	Inert Gas (nitrogen)	Air (nitrogen remain inerting the RSO bunker line)
When Procedure complete	Temperature	Ambient	Ambient	Warm LNG (just above -160ºC)	LNG	LNG	LNG vapour	Warm LNG (just above -160ºC)	Ambient	Ambient
Environmental Risk Assessment	Potential for Methane release	▪ No potential methane release	▪ No potential methane release	▪ Potential for methane release if connections are not tight.	▪ Potential for methane release if connections are not tight. ▪ Potential pressure increase if RSO tank not cold enough (leading to PRV release)	▪ Methane release can occur if filling rate is not adjusted/ reduced when the tank filling is above 90% ▪ Tank overfilling leading to PRV release	▪ Potential for methane release due to overpressure in the bunkering transfer line (trapped volume) ▪ Potential for release is higher if ESD is used to stop bunkering.	▪ Liquid LNG in the bunkering line to vaporize onto RSO tank. ▪ If pressure in RSO tank exceeded (by excess of LNG vapour) PRV may be released.	▪ Operation with the highest potential for methane release. ▪ When displacing LNG vapour from the bunkering lines with nitrogen there is the risk of sending mixture to the atmosphere.	▪ Methane release to the atmosphere is possible if gas reading confirmation <2% methane has not been properly done.
Environmental Risk Assessment	Methane Release Mitigating Measure	▪ **Bunkering hoses to be properly connected.** ▪ **Standard QC/DC to be used** ▪ **Flanges inspected before connection for dirt, moisture or condensations**	▪ **Check connections for leakages.** ▪ **Where any leak is suspected, stop Inerting for tightening/repair.** ▪ **Pressure test bunkering line**	▪ **Check connections for leakages.** ▪ **Where any leak is suspected, stop coo-down for tightening/repair.** ▪ **Pressure test bunkering line and inert.**	▪ **Start bunkering transfer only when temperatures are checked and agreed for stable transfer.** ▪ **Check carefully pressure at the receiving**	▪ **BFO and RSO to agree on a top-up rate.** ▪ **Carefull monitoring of pressure and tank level throughout bunkering transfer.** ▪ **Do not use ESD for automatic sut-down by high tank level**	▪ **Valve from the RSO to remain open for draining - purging.** ▪ **Control required from BFO to ensure that supply tank remains at adequate temperature and pressure.**	▪ **Drain procedure to be properly controlled.** ▪ **Ensure maximum LNG is drained in liquid form, minimizing the need to vapourize.** ▪ **Straighten "U" shapes in the hose to avoid LNG accumulations**	▪ **BFO and RSO should agree how to properly manage and dispose of the remaining NG and N2 so that no methane release occurs.** ▪ **NG/N2 mixture to be either compressed back to proper BFO tank, or consumed in GCU.**	▪ **Careful measurement of methane concentration before disconnecting hoses.** ▪ **Repeat Inerting procedure if concentration is >2%.**
				VAPOUR MANAGEMENT - Vapour management **should be agreed between BFO and RSO, in strict observation of PAA requirements on this matter.** - **Options**: 1) accumulated in the RSO tank as NG compressed on top of the tank; 2) Top-spray filling to reduce pressure; 3) Vapour return lines for BOG collection by BFO; 4) GCU (BFO or RSO) or 5) re-liquefaction on either side						

Figure 10. Potential methane release and mitigating measures during the LNG bunkering procedure

Source: EMSA Guidance on LNG Bunkering to Port Authorities/Administrations, Figure 3.6

LNG Bunkering/ LNG small Scale supply chain	Potential release scenario	**Methane Release - Risk mitigating measures**	
		Technical	**Operational**
LNG bunker vessels/barges  (LNG vessel/barge filling operation in small-scale LNG storage facility)	If the tank is not in Cold condition (BOG temperature <120ºC) filling with new LNG will generate excessive BOG. **Release of LNG vapour may occur if MARVS is exceeded. PRV will open to relief pressure.**	▪ Provide technical means to cool-down with own LNG or Inert Gas/ Nitrogen ▪ Cool-down with nitrogen plant or own LNG vapour.	▪ **Plan for LNG loading in cold condition (either LNG or Nitrogen)** ▪ **Avoid waiting times in warmer tank temperatures.**
	During LNG loading, at higher rates, if vapour pressure is not properly controlled there is the probability to exceed MARVS. **Release of LNG vapour may occur if MARVS is exceeded. PRV will open to relief pressure.**	▪ Adequate monitor for LNG tank vapour pressure. ▪ Communications and ESD high-pressure actuation for last resource.	▪ **Top-bottom filling of LNG fuel cargo tank to allow cool-down of top vapour side of the tank.**
	If the bunker barge/vessel LNG fuel cargo tank already contains older (aged) LNG there is the possibility for stratification. **Probability for "rollover" with peak excessive BOG generation.**	▪ Follow preventive technical measures for detection and prevention in SIGTTO Guidance [31]: *Guidance for the Prevention of Rollover in LNG Ships*	▪ **Definition of clear onboard procedures for corrective measures once stratification is detected.** ▪ Follow preventive operational measures for detection and prevention in SIGTTO Guidance [31]: ▪ *Guidance for the Prevention of Rollover in LNG Ships*
	If the bunker barge/vessel LNG fuel cargo tank is loaded with LNG/nitrogen mixture there will be the possibility for auto-stratification to occur. **Probability for "rollover" with peak excessive BOG generation.**		
LNG bunker vessels/barges  (LNG bunkering transfer operation) (bunkering with vapour return)	During LNG bunkering transfer to receiving ship, especially for large bunkering volumes, at higher transfer rates, it is possible that large amount of BOG is generated. **Possibility of methane release if LNG vapour return is such that vapour pressure in bunker vessel LNG tank exceeds MARVS.**	▪ One, or a combination, of the following technical measures shall be considered to manage large columes of LNG vapour [31]: ▪ **Pressure accumulation,** ▪ **LNG vapour re-liquefaction system,** ▪ **Burning** of natural or forced BOG in an approved consumer such as a Gas Combustion Unit, dual fuel diesel engine or other approved combustion unit. ▪ LNG **fuel cargo cooling**	▪ **Ensure adequate pre-bunkering procedures to be followed by BFO and RSO.** ▪ **Condition prior to bunkering to be carefully checked.**
	If the receiving ship tank is not in Cold condition (BOG temperature <120ºC) filling with new LNG will represent high rate of vapour return. **Release of LNG vapour may occur if MARVS is exceeded. PRV will open to relief pressure.**		
	If the LNG bunkering line is excessively long (for instance, when the delivery and receiving flanges are far apart) excessive LNG vapour pressure may build-up inside the bunkering line. **Vapour pressure generated in the bunkering line will return through LNG vapour return line. Excess of LNG vapour may take MARVS to be exceeded. PRV will open to relief pressure.**	▪ Minimize length of LNG bunkering lines ▪ Use properly insulated hose whenever possible. ▪ For rigid arms use vacuum insulated feeding and bunkering pipes where possible	▪ **Bunker vessel/barge delivery manifold station to be as close as possible side-by-side to LNG receiving vessel bunkering station** ▪ **Minimization of trapped volume**
	If draining/purging/inerting procedure is not adequately performed there is the possibility that some LNG/NG will remain in the bunkering line. **Release of LNG vapour may occur if bunkering hoses are disconnected with LNG/NG still in some point of the line.**	▪ Gas measurement to be performed before hose is disconnected. ▪ Avoid formation of "U" shapes where LNG can lay arrested.	▪ **Ensure draining is effective.** ▪ **Check for the existence of exterior ice cap (as an indicator for the presence of LNG inside the line) – heat up with water.**

Figure 11. Methane release and mitigations for LNG bunker vessels and barges

Source: EMSA Guidance on LNG Bunkering to Port Authorities/Administrations, Table 3.4

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