LPG Bunkering

Guide for LPG Marine Fuel Supply

Innovation & Technology

World LPG Association (WLPGA)

The WLPGA was established in 1987 in Dublin and unites the broad interests of the vast worldwide LPG industry in one organisation. It was granted Category II Consultative Status with the United Nations Economic and Social Council in 1989.

The WLPGA promotes the use of LPG to foster a safer, cleaner, healthier and more prosperous world.

Acknowledgements

This report has been developed by the Innovation & Technology Network of WLPGA and members of the Marine Working Group.

There could be views expressed in this document not necessarily shared by all contributors.

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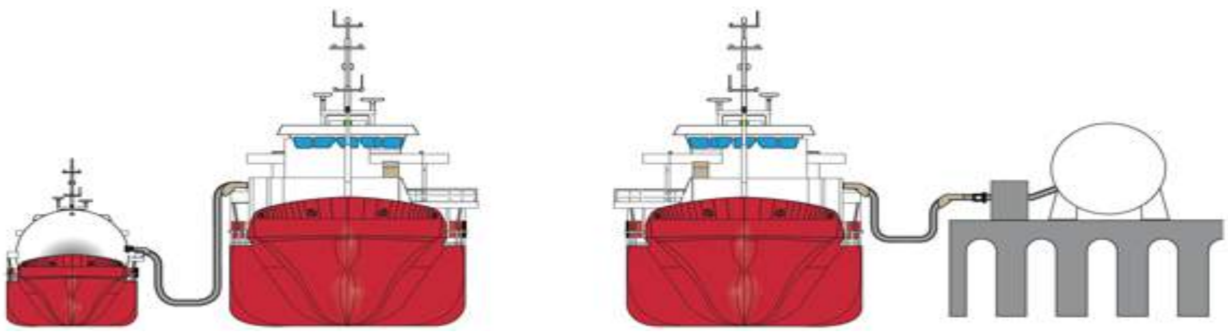
Chapter One

Introduction

LPG is one of the cleanest burning fuels available today with negligible sulphur content.

LPG bunkering is the practice of providing LPG as fuel to a ship for its own consumption. The key advantage of LPG as a fuel when burned in an engine, is that it can produce low levels of NOx (depending on engine type) and less CO_2 than other marine fuels and it offers a vast reduction in all other pollutants (including spillages during transfers) caused by the use of traditional marine fuels such as heavy fuel oil (HFO), marine diesel fuel (MDO) and marine gas oil (MGO).



LPG is becoming a technically and economically feasible option as an alternative fuel for shipping. The key regulatory driver is the stricter environmental policy designed to reduce or control traditional air emissions. The International Maritime Organization (IMO) has adopted emission standards through Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). The emission regulations in Annex VI include, among other requirements, a tiered compliance system introducing increasingly stricter limits on emissions of sulphur oxide (SOx), nitrogen oxide (NOx), and particulate matter (PM). In addition to global requirements, designated areas called emission control areas (ECAs) are subjected to more stringent requirements for the same emissions.

With IMO introducing the new sulphur cap of 0.5% from 2020, demand for LPG bunker fuel is expected to rise, since LPG enables almost complete reduction of SOx emissions and a very significant reduction of NOx and CO_2 emissions. Meanwhile, the key economic drivers are high LPG bunker fuel availability and relative competitiveness of LPG prices. Thus, depending on the circumstances, LPG can be the most cost-efficient option, considering that it is required to build a global network of LPG bunkering bases in order to further promote LPG fuelled ships and of actions to take, in order to “pave the way” for take-up in the marine routes.

The report scope mainly includes:

- An overview of key LPG bunkering developments and how this potential infrastructure relates to major global shipping routes, traditional oil bunkering ports, and the bulk LPG infrastructure which will provide the foundation for future LPG bunkering service.
- A description of current and future LPG infrastructure investments around the world. This scan covers primarily Europe, USA, Asia and some highlights from other parts of the world.
- An incorporation of various case studies describing the bunkering projects being developed at specific locations.
- Barriers to growth and recommendations.

The report aims at supporting LPG distribution companies, States policy-makers, ports and ship owners to develop LPG bunkering and to comply with Marpol Annex VI and Directive 2012/33/EU in the most efficient way.

This WLPGA report aims to improve understanding by members of the maritime industry and specifically the issues involved with bunkering ships with LPG. Some of the key areas that are addressed in this report are design issues, current thinking on possible solutions to the requirements of regulations, safeguards and safe practices, as well as important areas of operational processes and training.

This report contains:

- **A 'fact sheet'** giving an overview of the current LPG bunkering developments and main players in the value chain. It is intended to provide guidance on the technical and operational challenges of LPG bunkering operations.
- **A 'roadmap'** providing stakeholders with different types of bunkering systems, exploring the LPG infrastructure in different regions and identifying the drivers and barriers for future growth.
- **Recommendations** targeting stakeholders and association members on how to overcome the barriers for increasing LPG bunkering presence around the world and also on maximising the market opportunity with infrastructure.

This report belongs to the group of studies that have been elaborated under the framework of the LPG as marine fuel footnote to report.

Chapter Two

Executive Summary

2.1. Key Messages - Fact Sheet

Environmental regulatory pressure is building to cut emissions caused through ship transportation. It is this imposition of stricter sulphur content limits to marine bunker fuel and the tightening of international regulations on emissions from shipping that is driving LPG Bunkering system design as well as the development of a LPG fuelling infrastructure. The declaration of an Emission Control Area (ECA) of 200 nautical miles around the Asia, Europe, North America, coastline is a typical development.

One viable option for meeting these demands for reduced emission is to utilise LPG as a marine fuel. Due, the conversion of ship fuel from HFO to LPG with cleaner emissions is expected to proceed to LPG fuelled ships. Considering that it is required to build a global network of LPG bunkering bases in order to further promote LPG fuelled ships.

LPG as a bunker fuel The two primary drivers that make LPG appear an attractive alternative are:

- Compliance with emissions regulations. LPG allows ships to meet MARPOL Annex VI requirements for both worldwide trades and operation in ECAs as its sulphur content that is well below the requirements for ECAs. Moreover, LPG reduces NOx emissions to levels that will meet MARPOL Annex VI without need for after treatment.

- Economic and cost drivers, including fuel costs, repowering and new builds, availability and costs of LPG. LPG is lower priced than HSFO on a heating value basis. The main drawback of LPG are the uncertainties in future LPG price levels.

The attractiveness of LPG as ship fuel compared to other compliant options depends on three parameters:

- Share of operation time of the vessel spent inside ECAs.
- Price difference between LPG and HFO, LSFO, MGO.
- Investment costs for LPG tank and fuel system.

The global LPG production in 2017, was 308mn tonnes, up from 305mn t in 2016, a year-on-year increase of 1.4 %. LPG supply is soaring in the wake of rising global natural gas production. Production growth will continue to come mostly from the US, whereas Asia will lead the increase in demand.

The market for LPG as a bunker fuel estimated that will grow significantly over the next few years. Demand for LPG is rising, particularly in the residential and commercial sectors of developing and more developed countries. The use of cleaner liquid and gaseous fuels is expected to continue to increase as populations grow and total demand for energy in these regions rises proportionally. At the same time, oil and gas prices have risen to improving the economics of LPG resulting in stronger transportation demands for LPG.

With a number of marine infrastructure LPG projects already in the planning stage, many more are expected in the coming years. As access to LPG increases and markets open up, offshore terminals will increasingly play an important role in the overall safety and efficiency of these projects. LPG is today a technically feasible option as an alternative fuel for shipping and present an interesting uptake, especially in some ship types.

LPG bunkering companies **can build upon the excellent standards set by bulk LPG shipping**, which has one of the most safety records in any marine transportation sector.

LPG bunkering ships have a significant role to play in the shipping sector, that is going to be fuelled by LPG or to incorporate LPG readiness in their future new builds.

The industry is well prepared for LPG as fuel. Studies performed in ports have shown that, where technical, operational and commercial constraints exist, LPG bunkering is better served by LPG bunkering vessels than truck loading or via jetties.

LPG bunkering can in principle take place in many different ways, e.g. from terminals or trucks on-shore or from bunkering vessels. Bunkering from terminals to LPG-carrying ships, is today handled safely with proper specialized training, and the safety is believed to be further improved by using a bunkering vessel as an intermediate between the terminal and the ship using LPG as fuel.

Bunkering of larger ships in a harbour area is normally done by ship to ship transfer. This is likely to be also the case for LPG bunkering. For smaller ships bunkering, road or rail tankers is likely to be the most economic and convenient option.

There are certain regulations to consider, when individual local authorities and the responsible port authorities need to permit LPG bunkering at the chosen location.

LPG can effectively be supplied as a bunker fuel to vessels using **existing facilities such as terminals and refineries,** saving on initial costs to develop infrastructure. **There are likely to be more than 1,000 such facilities that offer LPG storage around the world**.

While LPG offers notable economic and environmental opportunities, its successful implementation has still some possible barriers to overcome. Many different actors have a considerable interest in the topic, such as ship owners, ports, gas suppliers and policy makers that makes often decisions complicated. These stakeholders are very important in the development process and their involvement is vital.

2.2. Key Messages - Roadmap

LPG as fuel for shipping, as an emerging market segment, is bringing new ship designs, technical options and operations. Mostly driven by higher risk-taking funding/investment initiatives, LPG bunkering has to incorporate customised solutions. This is the case for ship designs with specific LPG fuel systems, in terms of capacity and technology. The same holds also for operations, where the need to continue ship operations, at the same time with LPG bunkering, is one of the essential elements for the viability of LPG fuel option for some types of ships (e.g. containerships or RO-PAX ferries).

LPG bunker fuel long term growth pace is subject to various regulatory and economic challenges. Given the continuing pressure on the shipping industry to improve its GHG footprint, ship owners may prefer to wait for new lower carbon options. Meanwhile, the key economic challenges are costs of LPG bunkering infrastructure and costs of retrofitting conventional ships to use LPG bunker fuel. The routing possibilities for LPG-fuelled ships remain unlimited due to the wide global distribution of LPG storage and terminal facilities.

There are inherent market characteristics, which support the development of LPG as bunker fuel:

- The regulatory drive towards stricter emissions standards in force around the world.
- Replacement of old engines to comply with new regulations create market opportunities.
- Attractive LPG price.
- Business and industrial market growth.
- Sufficient supply of affordable LPG over the forecast horizon.
- Increasing awareness of the advantages of new technologies.

The uptake of LPG propulsion to be determined by three main drivers: regulatory, operational and market.

- The first driver type is regulatory change. This category involves the regulations that governments apply, for example, in terms of reducing emissions of air pollutants at sea, with emission control areas in the North and Baltic Sea. There is an uncertain pace of expansion of ECAs. IMO adopted Interim Guidelines on Safety for Gas Fuelled Engine Installations in Ships. IMO also convened a working group to draft an International Code of Safety for Ships Using Gases or Other Low Flashpoint Fuels (IGF Code). The question is how broadly accepted those regulations (for domestic trades) in international trades are. If the IGF Code requirements are more stringent than those of the Interim Guidelines, what will the effect on ships built under the Guidelines be.

- Operational drivers cover the technological push and eventual cost savings. The technological push stems from the availability of specialised engines from equipment manufacturers and ship builders who are able to install them on new-built or retrofitted ships. Cost savings arise from differences in energy prices. High oil prices push ship owners to consider alternative fuels to save on bunker costs in comparison with conventional fuels. Since the introduction of market-based prices, e.g. for LPG coming from North America, LPG prices have become increasingly de-linked from oil prices. Accordingly, long-run price competitiveness and regional price advantages can favour alternative fuel investment strategies of carriers. Evidently, there is currently no LPG bunkering price and thus it is difficult to make accurate comparisons between competing fuels. This also explains why for the moment only LPG carriers have expressed an interest in using LPG propulsion. At least one of these new builds and retrofits is underpinned by a long-term time charter to a large LPG producer who themselves will be responsible for the bunkers**. Until there is an accepted LPG bunker price it seems unlikely that any commercial LPG-propelled vessels (of any type) will trade in spot markets where the vessel's owner will be responsible for bunker costs.**

- The third driver type are market factors that include the preferences of ship owners or clients who may choose cleaner or greener shipping options or request specific ship bunker fuels. Currently however, we see fairly limited evidence for ship owners being ready to pay higher prices for cleaner fuels to be used for freight transport.

Fuel suppliers are waiting for demand before investing while shipping companies are waiting for supply before further investing in LPG bunkering. Coordination and cooperation between port developers and ship owners will be particularly difficult with ships in international trades.

The main barriers to industry-wide decarbonisation lies with the industry's composition; it is largely privately owned, and both ship owners and charterers are driven by short-term cyclical patterns. So far, public environmental concerns have not effectively been translated into any tangible pressure.

Incentivising ship owners is further complicated by the fact that they are responsible for investing in fuel-efficient technologies whereas it is the charterers who, in most cases, pay for fuel. As a result, only a small part of the fuel savings is passed back to the ship owners. Nevertheless, financiers have an important role to play in helping the industry move towards effective decarbonisation. There has been an increasing desire to hold greener portfolios, which stems from a practical need to mitigate against the risk of future (and more stringent) environmental regulations that could directly impact the value and liquidity of vessels, as well as the profitability of potential loans.

2.3. Key Messages – Recommendations

With IMO2020 being already almost present, LPG will make inroads into the marine fuel market. LPG propulsion has to gain widespread acceptance in the LPG shipping sector. However, for it to move beyond being a niche fuel it has to proliferate beyond the LPG carrier sector.

Owners, operators, designers and shipyards around the world are considering the advantages that operating on LPG may provide. However, when considering any new or evolving technology, it is important to have a clear understanding of not only the benefits, but the challenges that may be involved.

At least for deep sea shipping with significant amounts of fuel to be bunkered, a bunkering vessel would be the preferred solution for their refuelling.

There are different possible combinations of bunkering vessels with pressurized tanks or semi-refrigerated tanks and similar arrangements in the ship to be bunkered.

Main drivers of LPG bunkering infrastructure development:

- Increased availability of LPG supply will drive to long term growth in demand for LPG as fuel.
- Major port trading hubs are well located to the existing LPG storage facilities that could supply LPG bunker for ships, if demanded by owners.
- Desire for charterer's and shippers to improve green credential.
- Gas fuelled fleet "projected" to grow to 250 by 2020, so there is an increased awareness for clean fuels.

For the successful implementation of the LPG bunkering development it is important to:

LPG exporting countries to consider becoming first movers instead of just taking a wait-and-see position, since the LPG bunkering market promises to be highly competitive. These countries have great potential to become international LPG bunkering hubs.

Involve stakeholders in the development of policies governing LPG bunkering
There is a range of players with a stake in the development of LPG bunkering. These include LPG importers, global and coastal shipping companies, as well as firms with a high degree of expertise in storage and handling of LPG.

Plan LPG infrastructure in a flexible manner
The uptake of LPG propulsion by the shipping sector is increasing, but its perspectives are far from certain. In order to avoid over-investment, the LPG bunkering strategy should be flexible and able to scale up when demand grows. Ship to Ship transfers will be a viable solution.

Stimulate international cooperation in LPG bunkering services
Increasing the number of LPG-propelled vessels significantly requires a world-wide network of LPG bunkering facilities. LPG Associations have to be active in international coordination efforts, for instance Conferences. These efforts need to be sustained. Associations could bring together the relevant world ports for LPG bunkering and facilitate the harmonisation of technical standards in LPG bunkering. It could also promote transparent global LPG markets, building on its experience and expertise in handling LPG.

The conclusion from this report is that:

- **Sufficient potential infrastructure for distribution of LPG is available to serve potential marine market demand**
- **Engine technology for using LPG as fuel has been developed for a wide range of power outputs.**
- **The economic incentive in the fuel price difference alone is going to attract more ship owners to invest in LPG fuelled fleets in the near future and use as bunker fuel.**

Chapter Three

Fact Sheet

This Fact Sheet provides an overview of the product, the LPG bunkering options and the major LPG potential bunkering hubs in global regions. It provides a snapshot of the main players on the global LPG bunkering market and details on the most important ones.

3.1. The Product – LPG Marine Engine Fuel in a Nutshell

LPG Composition

LPG is a lower pressure gas predominant mixture of propane and butane (normal and isobutane) with a small percentage of unsaturated hydrocarbons (ethylene, propylene and butylene) and traces of lighter hydrocarbons (ethane) as well as heavier hydro- carbons (pentane). LPG composition depends on the source from which LPG gas is produced (crude oil and natural gas production fields or oil refining). In most places in the world LPG is propane while in other places it consists of butane or a mixture of both propane and butane. The composition of the liquid phase and vapour phase depends on the pressure. It can be obtained from the equilibrium diagram for propane/butane mixtures at the considered pressure.

LPG boiling temperature

LPG has a boiling temperature depending on composition and usually ranging from − 42 °C (pure propane) to − 0,5 °C (pure n-butane) at atmospheric pressure.

Vapour pressure

LPG has a vapour pressure depending on composition and ranging from:

- 1.8 bar (pure n-butane) to 7.3 bar (pure propane) at 15°C
- 4.3 bar (pure n-butane) to 15.3 bar (pure propane) at 45°C

Density of gaseous LPG

The density of gaseous LPG depends on the composition and usually ranges from:

- 1.89 kg/m3 (pure propane) to 2.54 kg/m3 (pure n-butane) at a temperature of 15°C and atmospheric pressure.
- 1.69 kg/m3 (pure propane) to 2.25 kg/m3 (pure n-butane) at a temperature of 45°C and atmospheric pressure.

The above figures are to be compared to the density of air at atmospheric pressure: 1.22 kg/m3 at 15°C and 1.11 kg/m^3 at 45°C. Gaseous LPG is much heavier that air and hence, in case of leakage in a space, it settles down at low points.

Flammability

The flammability characteristics of gaseous LPG are as follows:

- LFL (Lower flammability limit) by volume in air: between 1.4% (n-butane) and 1.7% (propane) according to EN1839

- UFL (Upper flammability limit) by volume in air: between 9.4% (n-butane) and 10.8% (propane) according to EN1839
- auto-ignition temperature (EN 14522): between 392°C (n-butane) and 459°C (propane), higher than that of MGO (300°C).
- minimum ignition energy: 0.25 mJ, lower than that of many hydrocarbons.

The term "LPG", Liquefied Petroleum Gas, is applied to mixtures of light hydrocarbons which can be liquefied under moderate pressure at normal temperature but are gaseous under normal atmospheric conditions.

In some countries, the mix varies also according to the season. Since LPG can be liquefied at low pressures at atmospheric temperature, its storage and transportation is easier than of other gaseous fuels. It is stored in tanks under pressure, semi refrigerated or refrigerated.

LPG is produced either from natural gas processing – mainly – or from oil refining and recently from Bio sources. LPG is a by-product of all these processes. At present, more than 60% of global LPG supply comes from natural gas processing plants, but the share varies markedly among regions and countries. It is not only available and abundant in supply, but it is also economical and environmentally sound.

Global demand for LPG surpassed 308 mn tonnes for the first time in 2017[1].This milestone reflects the strong growth that the sector has seen over the past decade.

LPG is a viable alternative gaseous fuel

It has high energy density compared with most other oil products and other alternative fuels and burns cleaner in the presence of air. It has high calorific value compared to other gaseous fuels and also high-octane number (but a low cetane number). Its high-octane number makes it suitable for spark ignition engines (SI), while its low cetane number makes it less favourable for use in large proportions in compression ignition engines (CI) – diesel engines.

Transportation

The global LPG export was approximately 90 million tonnes in 2017[2]. LPG can be transported by three different ship types, depending on how the cargo is stored:

- refrigerated, typically at -50°C at close to ambient pressure.
- semi-refrigerated, typically at -10°C and 4-8 bar pressure.
- under pressure, typically at 17 bars, corresponding to the vapour pressure of propane at about 45°C.

There are currently 266 VLGCs in service and 36 on order[3]. Twenty-two of the ships on order were due for completion over the rest of year, and 14 in 2020. In 2020, when the ships currently under construction are completed, the VLGC fleet will stand at 302 vessels.

There are currently about 200 very large gas carriers (VLGCs) that can transport some 80,000 m^3 of LPG. Semi-refrigerated ships typically have a capacity of 6,000 to 12,000 m^3, whereas pressurised LPG ships typically take 1,000 to 3,000 m3.

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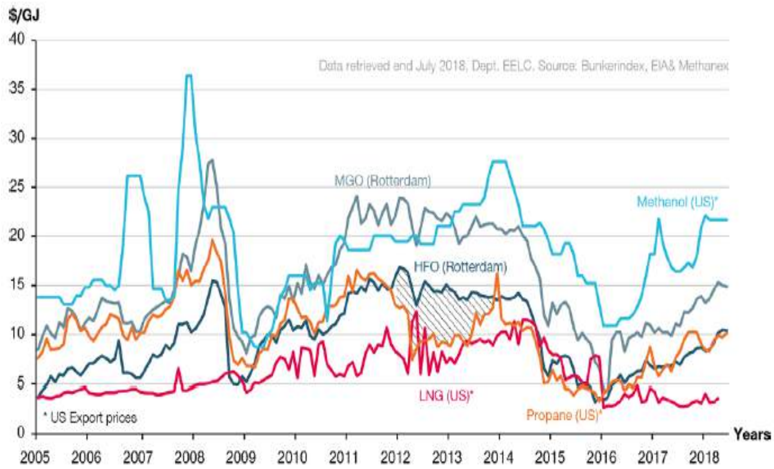
[1] Statistical review of Global LPG, WLPGA & Argus
[2] Clarksons Platou
[3] Vessels value

The transportation of LPG is covered by the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), which is aimed at the safe carriage of liquids with a vapour pressure above 2.8 bar at 37.8^{O}C, and applies to all ship sizes. If an LPG carrier is to be powered by LPG, this is in principle for this particular ship type covered by the IGC Code without having to comply with the IGF Code (International Code of Safety for Ship using Gases or Other Low-flashpoint Fuels). However, the IGF Code can be used for further clarification. For other ships, the use of LPG as fuel has to be covered through alternative compliance with the IGF Code.

Pricing

Historic prices of Brent oil, LPG and Natural Gas

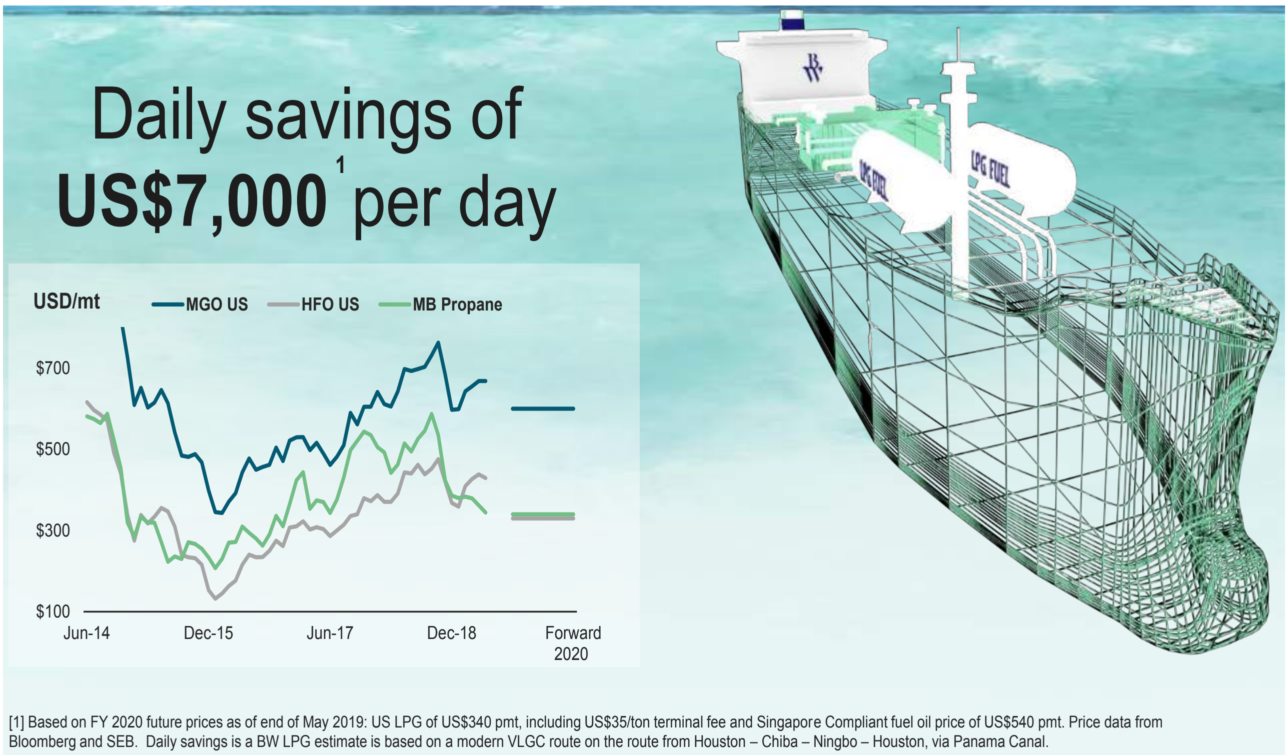
Since 2011, LPG had been sold in the USA, on an energy basis, at a discount to crude oil, but significantly higher than that of natural gas as shown on the Figure.



Historic prices of HFO, MGO, LPG and LNG, 2010–2018

However, a decoupling of LPG and oil prices, and the reduction in the price of LPG was later observed and can be attributed to the increased yield of propane from shale gas production. This development also resulted in the USA turning from a net importer into a net exporter of LPG after 2011.

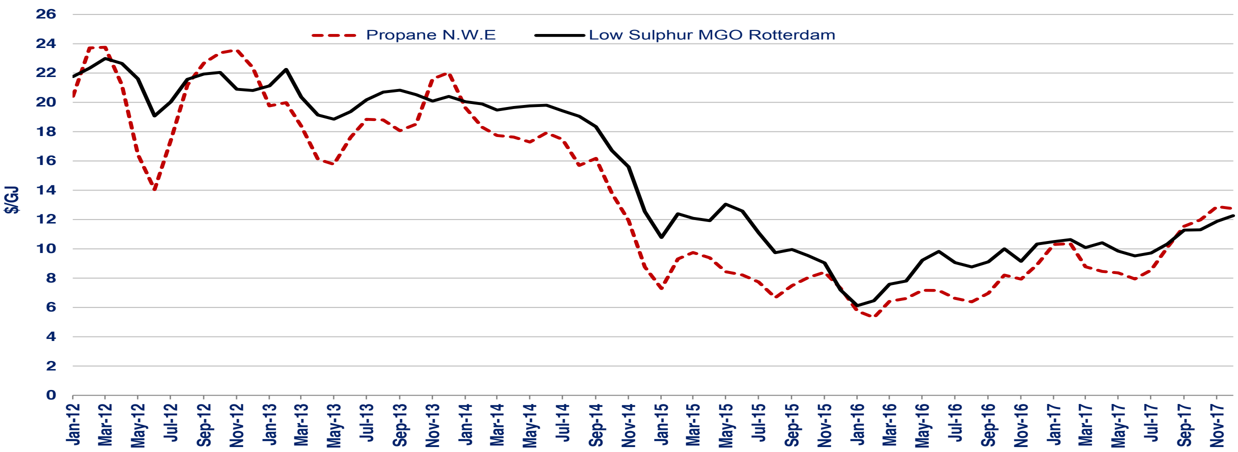
The drop-in oil prices since 2014 has affected the prices of not only various oil-based fuels, but also natural gas, methanol and LPG, as illustrated in the Figure.



The extent to which each fuel has dropped in price varies, and the relative position of the fuel price has changed over time. For example, LPG prices were at the same level as or lower than LNG prices in the USA in 2015. For the last few years, LPG has on average been cheaper than HFO in the USA. On the other hand, methanol has become more expensive than MGO in the last three years.

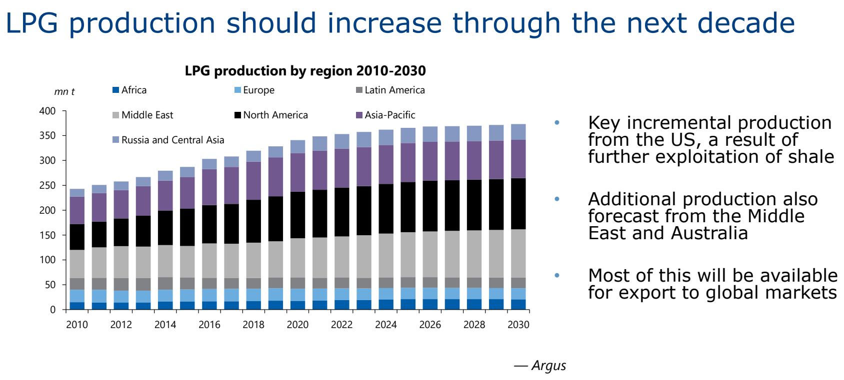
Normal butane has about 10% higher volumetric energy density than propane, and is typically less expensive. Therefore, the use of propane or propane-rich mixture of LPG is expected for small boats, while butane to be used for bigger when LPG is used as fuel for ships.

LPG has attractive price[4]



3.1.1. Supply and Availability

The global LPG production in 2017, was 308mn tonnes, up from 305mn t in 2016, a year-on-year increase of 1.4%. LPG supply is soaring in the wake of rising global natural gas production. The US is the main supply of incremental production going forward considering that many of its gas deposits are especially wet which means that they contain a large fraction of gas liquids such as butane and propane. Indeed, for the moment, supply is outstripping demand and this is projected to continue over the medium-term.

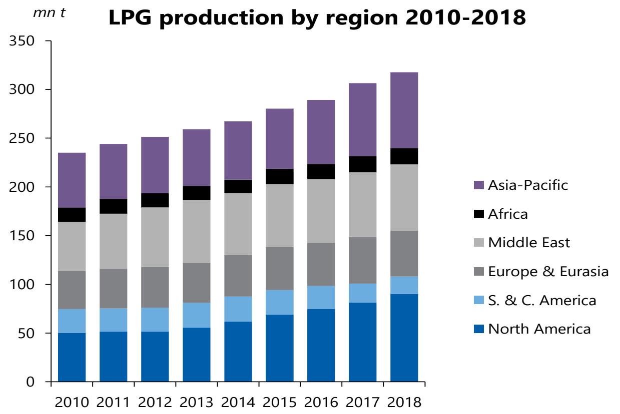


This surplus could hit 27 million tonnes per year going forward[5].

Production estimate around 375 million ton by 2025[6]

[4] Clarksons Platou
[5] WLPGA
[6] IHS Markit

This overhang represents approximately 12% of global international bunkering demand. **A large network of LPG import and export terminals is available around the world to address trade needs**. Recently more LPG export terminals have been developed in the US to cover the increased demand for competitively priced LPG products. There are many import and export terminals of various sizes in Europe while many other storage facilities can be found in several additional locations. In these locations, it is possible to develop bunkering infrastructure by creating distribution systems in addition to the existing storage facilities.



— Argus/WLPGA

Production growth will continue to come mostly from the US, whereas Asia will lead the increase in demand. The output of US shale gas, and downstream products such as LNG, LPG and ethane, remains on an upward curve. The May 2018 forecast by the US Energy Information Administration (EIA) has the country down for an increase in net LPG exports to 29.3M tonnes in 2018, implying a year-on-year growth of 8.0%. EIA goes on to predict a 16.5% rise in net US LPG exports in 2019, to 34M tonnes; the majority of this cargo will be carried in VLGCs. Interestingly, two new Australian LNG export projects are poised to add 2M tonnes per annum (mta) to global seaborne movements of LPG.

The Prelude floating LNG production (FLNG) vessel off the coast of Western Australia and the Ichthys LNG terminal in Darwin are both due on stream in the coming months and both will produce LPG and condensate, as well as LNG from their respective gas fields. Despite these projects, and others in Canada and Angola, US exports are set to drive the expansion in the seaborne trade of LPG in the years ahead. **Almost 40% of US LPG production is directed at the export market and the inability of domestic consumers to absorb much more product ensures a healthy level of exports and sufficient supply of LPG as bunker fuel.**

Field Layout

3.1.2. Environmental Emissions to Air and Water

LPG combustion results in lower CO_2 emissions compared to oil-based fuels due to its lower carbon to hydrogen ratio. Compared to natural gas CO_2 emissions are a bit higher, but some gas engines can suffer from methane slip, which increases their overall greenhouse gas emissions. Considered in a lifecycle perspective, LPG production is associated with lower emissions than oil-based fuels or natural gas. The combination of low production and combustion emissions yields an overall GHG emissions reduction of 17% compared to HFO or MGO. This is comparable with the GHG emissions from LNG, which strongly depend on the amount of methane leak and could be slightly lower or higher depending on the production and combustion technology.

Greenhouse gas emissions in kg CO_2eq/GJ for oil-based fuels, LPG and LNG are given in the table below.

A methane slip of 1% and an energy consumption for liquefaction of 7% are assumed for LNG. Because the global warming potential for LPG and n-butane are three, and for isobutane four (times the global warming potential of CO_2)

compared to 25 for methane, any slip of un-combusted fuel through the engine would result in less GHG emissions for LPG than for LNG.

The use of LPG also has benefits related to pollutant emissions. It virtually eliminates sulphur emissions, and can be used as a means of compliance with low sulphur local and global regulations. The reduction of NOX emissions depends on the engine technology used.

	HFO	MGO	LPG	LNG (Qatar)
Well-to-tank	9.79	12.69	7.15	9.68
Tank-to-propeller	77.70	74.40	65.50	61.80
Well-to-propeller	87.49	87.09	72.65	71.48
Difference to HFO	**-**	**-0.50%**	**-17.0%**	**-18.30%**

For a two-stroke diesel engine, the NO_X emissions can be expected to be reduced by 10–20% compared to the use of HFO, whereas for a four-stroke Otto cycle engine, the expected reduction is larger and may be below Tier III NO_X standards. In order to comply with these standards, a two-stroke LPG engine should be equipped with Exhaust Gas Recirculation (EGR) or Selective Catalytic Reactors (SCR) systems. Both solutions are commercially available. The use of LPG as a fuel will, like LNG, to a large degree avoid particulate matter and black carbon emissions.

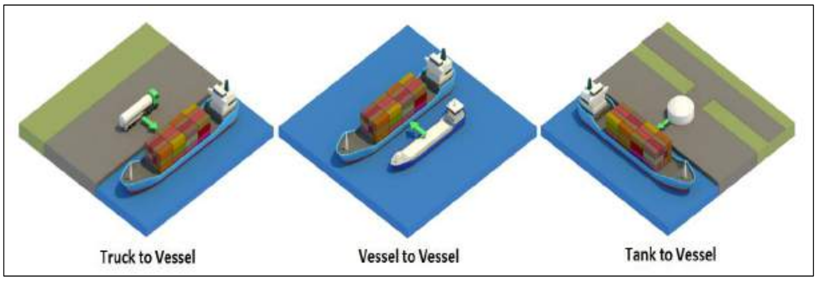
3.1.3. Main advantages of LPG as marine fuel

- Available in large quantities everywhere in the world and in production surplus. LPG supply is soaring in the wake of rising global natural gas production. The US is the main supply of incremental production going forward considering that many of its gas deposits are especially wet which means that they contain a large fraction of gas liquids such as butane and propane. Indeed, for the moment, supply is outstripping demand and this is projected to continue over the medium-term. According to the WLPGA, this surplus could hit 27 million tonnes per year going forward. This overhang represents approximately 12% of global international bunkering demand.
- Offers the longest running range of any alternative fuel option. Due to a higher-octane rating and efficient combustion, LPG engines can use higher compression ratios resulting in more power and better fuel efficiency.
- Meets worldwide IMO (International Maritime Organization) requirements, therefore a switch to LPG has significant potential in emissions reduction of hydrocarbons, CO, CO_2, elimination of SOx emissions also NOx, GHGs and PM in general.
- Reduces VOC evaporative emissions a new requirement in commercial ports around the world.
- LPG is nontoxic, hence not harmful to soil or water when spilled or leaked. Gasoline and diesel fuels in the water are harmful to humans and in many cases fatal to aquatic life. Floating fuels and oils are also particularly noxious because they reduce light penetration and the exchange of oxygen at the water's surface.
- LPG is stored at lower pressures than i.e. CNG making storage tanks lighter and more economical.
- Cleaner and easier to install, maintain and handle.
- Harnessing LPG propulsion translates into cleaner, more efficient engines that are cheaper to maintain. In addition, the fuel flexibility of dual-fuel engines ensures full redundancy for uninterrupted operations.
- It has lower lifecycle costs - lower cost for ship owner.
- It saves bunkering time for large LPG tankers that can use the cargo as fuel
- It is more economic (LPG prices vs fuel oil prices).
- It is an increasing availability of LPG network. Small investment is required to setup an LPG bunkering point.

3.2. Introduction to LPG Bunkering – The LPG Bunkering Interface

The market for LPG as a marine fuel estimated that will grow significantly over the next few years. Fuelling will have to be completed within tight time frames to meet ship sailing schedules and take account of simultaneous operations such as loading containers, vehicles or passengers. There is simply no margin for error if the operation is to be completed safely each and every time.

Fortunately, LPG bunkering companies **can build upon the excellent standards set by bulk LPG shipping**, which has one of the most safety records in any marine transportation sector.



The 50-year history of LPG cargo trade has undoubtedly proved that LPG can be transferred safely and efficiently.

This outstanding record was achieved by using well-trained crews and highly effective safety technology. In particular, the bulk LPG sector makes extensive use of linked ship-shore shutdown systems, in accordance with SIGTTO recommendations. Effective communication between the parties involved is critical to ensuring safe LPG bunkering. All those involved require a common understanding of the entire process arrangements.

Using LPG as a primary fuel is a relatively new endeavour. Several aspects of LPG use in shipping may be of stakeholders' interest. LPG as an engine, or "bunker," fuel potentially could help reduce harmful air emissions, it could create a new market for domestic LPG, and it could create economic opportunities in domestic shipbuilding.

The IGC and IGF codes do not address cargo loading and unloading operations or LPG bunkering transactions. In the case of gas carriers, the SIGTTO has developed various best practice publications and guidance.

LPG bunkering can in principle take place in many different ways, e.g. from terminals or road tankers on-shore or from bunkering ships and barges. Bunkering from terminals to LPG-carrying ships is today handled safely with proper specialized training. **At least for deep sea shipping with significant amounts of fuel to be bunkered, a bunkering ship would be the preferred solution**. LPG in terminals is typically stored onshore in steel spheres or cylindrical tanks (bullets), mainly under pressure, but LPG can also be stored in refrigerated tanks or underground.

The LPG may be stored under pressure or refrigerated, and LPG will not always be available in the temperature and pressure range that the ship can handle. The bunkering vessel and the ship to be bunkered must therefore have the necessary equipment and installations to bunker safely. The tank design temperature is related to the steel type used, and the minimum temperature for a pressurized tank is typically at or above 0^{o}C. Refrigerated or semi-refrigerated tanks typically have a design temperature of about -50^{o}C, but on the other hand have a limited pressure range compared to pressurized tanks.

There are different possible combinations of bunkering ships with pressurised tanks, semi-refrigerated tanks or fully refrigerated tanks and similar arrangements in the ship to be bunkered.

Four cases illustrate some key bunkering challenges:

- In the case of **pressurised tanks** both in the bunkering ship and the ship to be bunkered, the LPG is transferred using a general transfer pump located in the bunkering ship. When filling the LPG tank, pressure will build up because of less gas volume available, and since it takes time to condense LPG, this can increase fuelling time. For practical purposes and to comply with safety regulations, the LPG tank must be equipped with a vapour return system back to the bunkering vessel, i.e. a gas outlet connection in addition to the liquid inlet connection. This case represents the most common and cost-effective LPG bunkering option.

- In the case of **semi-refrigerated tanks** in the bunkering vessel and a **pressurised tank** in the ship to be bunkered, it is necessary to have a heater and a booster pump in the bunkering ship and a vapour return system in the ship to be bunkered. The heater is needed because the fuel has a lower temperature than the tank design temperature, and this will typically be handled by a heat exchange system using heat from seawater. The LPG filled will have a lower than ambient temperature, but needs to be above the tank design temperature. The booster pump is needed to raise the pressure of the LPG before bunkering. Both the heater and booster pump are typically installed on semi-refrigerated LPG carriers, that may be used as bunkering ships. The vapour return from the ship to be bunkered may have too high a pressure for the semi-refrigerated tank, and must be handled by the re-liquefaction plant in the bunkering vessel, which may require some modifications. An alternative to vapour return in this case is to fill the cold LPG with a spray-line to condense the LPG vapour.
- In the uncommon case of **pressurised tanks** in the bunkering vessel and a **semi-refrigerated tank** in the ship to be bunkered, the pressure needs to be reduced by lowering the temperature in a liquefaction plant. An LPG carrier with pressurized tanks is typically not equipped with this, thus requiring comprehensive modifications of the equipment and cargo handling system. This case also requires a vapour return system with a compressor in the bunkering ship that needs to be set up to increase the pressure of the vapour return. LPG carriers with pressurised tanks are typically equipped with a compressor, but only for the purpose of emptying the cargo tanks.
- In the case of **semi-refrigerated tanks** both in the bunkering vessel and the ship to be bunkered, cooling (and probably not heating) may be necessary. A vapour return system and some modifications of the re-liquefaction plant in the bunkering vessel to ensure a higher capacity may also be necessary.

Based on the cases discussed above, a pressurized LPG fuel tank is the preferred solution when bunkering the ship, because the ship can be bunkered by a bunkering vessel based on an LPG carrier (either with pressurised tanks or semi-refrigerated tanks) without major modifications. Both types of bunkering vessels are possible, depending on the size of the fuel tanks to be bunkered and the number of ships to be served. Semi-refrigerated LPG carriers typically have larger capacity than pressurised LPG carriers and sufficient capacity for all ship types. They are also more flexible, e.g. in terms of filling ships with semi-refrigerated fuel tanks, and have a limited cost premium.

Rules

- The provisions of NR529, Part A-1, Article [8], for LNG bunkering also apply to LPG, taking into account modification detailed in [7.2].
- Arrangement of the bunkering station. The bunkering station is to be arranged without low points or obstacles that could lead to LPG vapour accumulation.

LPG Bunkering Ships and Infrastructure

LPG feeder ships are small to medium-sized LPG carriers used for regional transport of LPG with a view to its use as ship fuel or the industrial use of LPG in remote places. LPG feeder vessels currently in operation or under construction are gas carriers with a capacity of 7,500-30,000 m^3. The size and main dimensions of the vessels will depend on market demand and the physical limitations of the intended unloading location, such as dimensions of the berthing site and draught at the jetty.

LPG feeder ships can be loaded at large LPG import/export terminals. Loading takes place via fixed pipes and flexible hoses or fixed arms at the typical rate of 1,000-6,000 m3/h depending on the size of the feeder ship. The LPG vapour displaced from the ship's cargo tanks is returned to the terminal via a vapour return line.

Unloading of the vessel at a bunker terminal or bunkering station is also done using fixed pipes and flexible hoses or fixed arms. The LPG is pumped to the terminal by the submersible pumps fitted in the ship's cargo tanks at a typical rate of 1,000 - 6,000 m3/h.

LPG Bunker Ship

LPG bunker vessels are small LPG ships, which could be used for the direct supply of LPG fuel to ships inside or outside a port. During bunkering, the LPG is pumped from the bunker ship's cargo tanks directly into the fuel tanks of the ship being supplied. LPG bunker ships are identical in design to LPG feeder ships and typically have a capacity of 500- 20,000 m^3.

LPG ships represent today a key role in the ability of LPG bunkering to be developed in capacity whilst avoiding the difficulties of shore side/ quay operation. LPG bunker vessels can be loaded at small to medium-sized bunker terminals or large LPG import terminals.

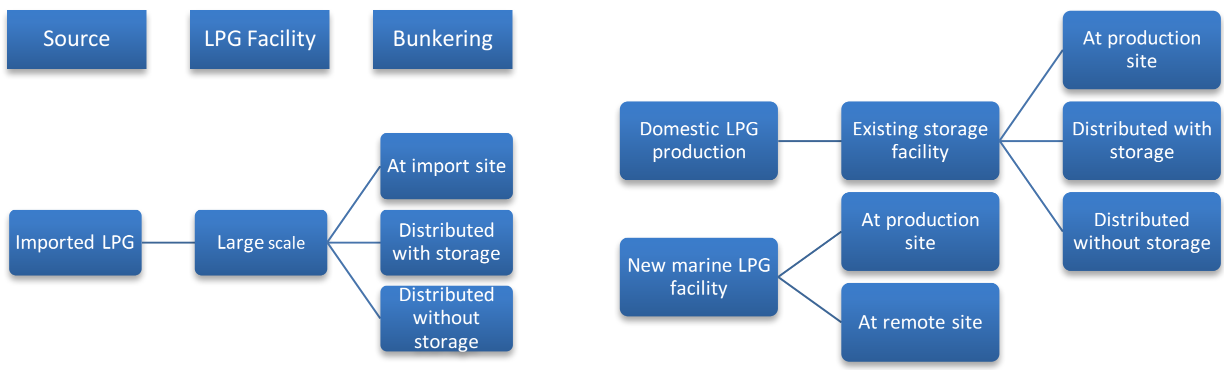
Bunkering is done using flexible hoses or fixed arms at a rate of 60-3,000 m3/h depending on the size of the fuel tanks on the receiving ship.

Rules applicable to LPG bunker vessels are typically IGC Code unless the bunker vessel is operating only in inland waterways, outside the scope of IMO IGC Code applicability. Here the applicable instruments would be defined at National Administration level. In the EU context the ADN agreement, Directive 2016/1629 or RVIR regulation would apply.

LPG Bunker Barges are, essentially, the non-propelled version of LPG bunker ships. All types of different LPG capacities and containment systems are possible, with a growing number of designs being developed. Mobility of these barges is subject to push-pull tug arrangements or to any other external propelling unit that deliver the barge the ability to be moved around the port area, responding to different LPG bunkering needs in potential different LPG bunkering locations. The use of a tug or external unit for mobility represents, on one hand, a clear flexible option that allows moving different floating units with one propelling craft. On the other hand, it may represent a challenge for manoeuvrability in higher traffic waterways.

LPG supply chain

There are a number of possible ways of bringing the LPG from the production well to the tanks on board a vessel in the form of LPG.
The pathways are differentiated by the source, the type of LPG facility, and the bunkering location and method.



3.3. LPG Bunkering Facility Models

A key requirement for ocean carriers to adopt LPG as an engine fuel is the availability of LPG bunkering facilities. LPG bunkering requires specialised infrastructure for supply, storage, and fuel delivery to ships. Depending upon the specific circumstances, LPG bunkering could require transporting LPG to a port from an offsite facility for temporary storage at the port, or building an LPG terminal on site. Alternatively, LPG could be delivered from offsite facilities directly to ships in port via road tanker or supply ship. There are three types of bunkering models:

- Truck (Road Tanker) to LPG Fuelled Ship (RTS)
- Shore (LPG Terminal) to LPG Fuelled Ship (PTS)
- Ship to LPG Fuelled Ship (STS)

Each LPG bunkering option may be a viable means to begin LPG bunkering service in a given port. However, ports may face practical constraints as bunkering increases in scale. For example, a container port of significant size typically has multiple terminals, it may need additional infrastructure or supply vessels for moving LPG to other port locations where a cargo ship might be berthed. There may also be port capacity and timing constraints upon the movement of LPG bunkering barges trying to refuel multiple large vessels in various locations around a crowded port. To date, the LPG bunkering operations already in development are comparatively small, but scale constraints could become a factor as LPG bunkering grows and might require additional bunkering-related port investments.

The construction of LPG bunkering hubs is currently under development. The transport and handling of LPG as cargo on land and sea have been proven for many years.

The choice of bunkering options will depend on the regulatory framework, local conditions, cost and operational considerations. The type of vessel and the size of the on-board fuel tank will to a great extent influence the bunkering method and the required transfer rate. Typically, based on the LPG tank size and vessel type, the table summarises the likely preferred or practical bunkering methods.

Vessel Type	LPG Tank Size (m3)	Bunkering Method
Workboat, Tug	ITB>100	RTS, Container
Ferries	100-200	RTS
OSV	>300	TPS, TTS
Ships	500-10,000+	STS

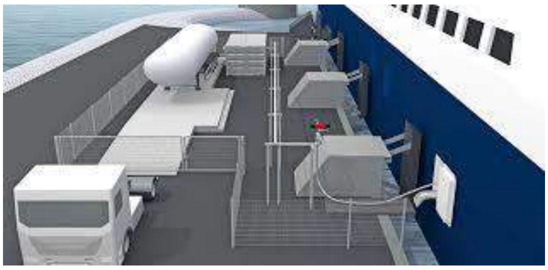
RTS is often the early phase adoption and for ships with small tank capacities such as ferries, tugs and coastal ships. The most efficient is considered to be STS.

3.3.1. Truck (Road Tanker) to LPG Fuelled Ship (RTS)

Road Tanker to Ship Transfer (RTS) bunkering is best suited for supporting smaller and mid-sized vessels, such as ferries or offshore supply vessels (OSVs) that support offshore oil platforms.

Facilities built on site can provide the greatest capacity of any LPG bunkering option, for example, to provide fuel for large vessels in transoceanic trade. However, constructing small- scale facilities to store and deliver LPG on site requires considerable planning and small capital investment, in one case on the order of $7 million for a mid-sized port.

This is about supplying LPG from a LPG road tanker parked on a quay to an LPG fuelled ship moored on a quay. Road Tanker to Ship, (RTS) LPG bunkering, in particular, provides some fuelling capabilities without minimal upfront capital investment. Supplying LPG using road tanker in this way may face capacity limitations due to truck size, road limitations, or other logistical constraints, but it has been demonstrated as a viable approach to LPG bunkering at smaller scales. LPG road tankers could also bring LPG to a storage tank built on site at the port, which could then bunker the LPG to arriving ships via pipeline. The type of infrastructure needed to temporarily store and deliver LPG within a given port would depend on the size and location of the port, as well as the types of vessels expected to bunker LPG.



Advantages

- Operational Flexibility
- Limited Infrastructure requirements
- Possibility to adjust delivered volumes (nr. of road tankers) to different client needs.
- Possibility to adapt to different safety requirements.
- Possibility to serve different LPG fuel users on point-to-point delivery

Disadvantages

- Limited capacity of road tankers
- Limited flow-rates
- Significant impact on other operations involving passengers and/or cargo.
- Limited movement on the quay-side, mostly influenced by the presence of the bunker road tanker(s).

3.3.2. LPG Port Terminal (shore) to LPG Fuelled Ship (PTS)

This is about supplying LPG from a LPG shore terminal or an LPG satellite terminal to an LPG fuelled ship moored on a quay or a pier. Fuel can be supplied to large ships. LPG is either bunkered directly from a small storage unit (LPG tank) of LPG fuel, small station, or from an import or export terminal.

Terminal Storage Tank to Ship: Ships arrive at a waterfront facility designed to deliver LPG as a fuel to the ship. Fixed hoses and cranes or dedicated bunkering arms may be used to handle the fuelling hoses and connect them to the ships. Piping manifolds are in place to coordinate fuel delivery from one or more fuel storage tanks.

Advantages

- Possibility to deliver larger LPG volumes, at higher rates.
- Good option for ports with stable, long-term bunkering demand.
- Bunkering, especially for ships with a short port turnaround time.
- Generally, does not interfere with cargo/passenger handling operations
- Operational flexibility – bunkering can take place alongside, with receiving vessel moored, at anchor or at station.

Disadvantages

- From operational perspective, it may be difficult to get the LPG fuelled receiving ship to the terminal.
- Proximity of larger LPG terminal may not be easy to guarantee.
- Calculation of available LPG for delivery, in small storage tanks, can be difficult unless pre-established contract exists.
- Initial investment costs involving design, procurement, construction and operation of an LPG fuelled ship/barge.
- Limited size for bunker ship, conditioned by port limitations.

3.3.3. Ship to LPG Fuelled Ship LPG (STS)

The predominant method of bunkering today is vessel to vessel, either by a tank barge or smaller tanker. This about bring an LPG bunkering ship along an LPG fuelled ship moored on a quay or a pier. With this method, LPG can be supplied to much larger ships.

A ship-to-ship (STS) bunkering operation is the transfer of bunkering supplies between seagoing ships positioned alongside each other, either while stationary or underway. Cargoes and bunkering supplies which are typically transferred via STS methods are crude oil, LPG or LNG, bulk cargo, and petroleum products

Some marine terminals allow barges to come alongside cargo ships while at their berths, thus allowing cargo to be loaded and the ship to be fuelled at the same time. Ship fuelling can also occur at anchorages. Ship to ship transfers are the most common form of bunkering for traditional fuel oil.

On open sea, this is called a ship-to-ship operation. One ship will act as the terminal whilst the other one will moor. The receiving ship is called the daughter ship and the delivering ship is called STBL (Ship to be lightered) or Mother ship. The supplying vessel has the hosing lines ready to deploy on the daughter ship. They are extracted with a crane coming from the supply vessel.

A hose will be connected between the two vessels and a pump, aboard the bunker barge, will force the liquid to be transferred via the hose. At first, the liquid will be pumped through the hose slowly, so the receiving ship can make sure it gets in the right tanks. When it does, the liquid will be pumped into the tanks at maximum pumping speed.

STS Bunkering

Advantages

- Ships do not have to divert their course; It takes a lot of time to enter a port only for bunkering. When a ship can be bunkered at sea, it can continue to its destination sooner.
- No waiting lines for a berthing place to get clear; When ships do not have to enter the port when they only have to bunker, they do not take up an extra berthing place. Ships that have to load or discharge can get a berthing place sooner.
- No port fees. When a vessel is entering a port, port fees need to be paid. These do not have to be paid when a vessel can stay at sea while being bunkered.

Disadvantages

- Bunkering at sea will never be as safe as bunkering while at berth; Even when fully researched, some factors will still be a problem. The main problem is the motion of both ships.
- Ships probably need slight adjustments to make sure they can receive the bunkering fluids; It will cost money to adjust ships that will receive the bunkers, not all shipping companies want to pay for this. This will reduce the number of ships that can bunker at sea, so some ships still have to enter the port when they only have to bunker.

- New sea-going bunker barges need to be developed. A sea going bunker barge needs a seaworthy hull and a large bunker beam. These adjustments will make the bunker barge more expensive to build than a normal bunker barge. The development will also cost money.

The provisions governing the design, construction and equipment of LPG bunker ships are the same of those for LPG carriers and are laid down in the International Gas Carrier (IGC) Code. However, designing a bunker ship is that much more daunting due to the range of fuelling operations and scenarios that they must accommodate.

Unfortunately, the criteria given for a static, shore-based facility would be inadequate for a ship-mounted version where the bunker vessel and the ship being fuelled are on the open sea and the vagaries of wind, tide and current conditions.

Risk assessments and simulations must also be carried out to achieve a true evaluation of the bunker ship's safe operating window.

On top of these considerations, the flag administration may stipulate that the bunker vessel complies with the International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF Code) for those parts that interface with the LPG-powered ship.

New era

A new LPG bunker-ship era is dawning thanks to the growing interest of clean-burning LPG as marine fuel, particularly in emission-control areas (ECAs). On top of this, a plethora of LPG ship and barge designs have been tabled over the past years.

STS transfers from LPG bunker vessels offer important advantages in terms of the ability to handle large volumes quickly, at a variety of locations.

Vessel Type		Existing Number of Vessels	Order Book	
			Vessels on Order	% of Fleet (# vessels)
Very Large Gas Carrier >60,000 cbm	Fully-Refrigerated	284	37	13%
Large Gas Carrier 40,000 - 59,999 cbm	Fully-Refrigerated	12	-	-
Medium Gas Carrier 25,000 - 39,999 cbm	Fully-Refrigerated Ethylene / Ethane	95 14	6 -	6% -
Handysize Gas Carrier 15,000 - 24,999 cbm	Fully-Refrigerated Semi-Refrigerated Ethylene	26 64 25	- - 8	- - 32%
Small Gas Carrier 5,000 - 14,999 cbm	Semi-Refrigerated / Pressure	332	16	5%
Small Gas Carrier <4,999 cbm	Semi-Refrigerated / Pressure	633	6	1%

Source: Clarksons, 2018

Source Epic Gas and IHS Markit

Market Breakdown by Vessel Class								
Class	CBM	Liquification Method	Service	# of Vessels	Total Capacity (CBM)	% of LPG Fleet by Capacity	Advantages	Disadvantages
Fully-Pressurized	0-13,000	Pressure	Last Mile	706	2,300,000	7%	• Low operating cost • Low asset cost	• Low cargo capacity • Restricted trade area
Semi-Refrigerated (incl. Eth)	3,000 - 23,000	Temp. / Pressure	Regional	300	3,300,000	10%	• Flexibility • Ease of construction	• High building cost • Complex operation
Mid-Size	20,000 - 45,000	Temp.	Medium / Long Haul	186	5,500,000	16%	• Highly efficient	• Lack of flexibility
LGC	45,000 - 65,000	Temp.	Long Haul	24	1,400,000	4%	• LPG carried in high weight-to-volume ratio	• Pressure limitation
VLGC	65,000 +	Temp.	Long Haul	269	22,000,000	64%	• Easiest tank construction	• Limited access to terminals and ports

Source Epic Gas and IHS Markit

Examples

ELEFSIS provide STS OPERATION of any size and a variety of cargoes including Crude Oil, LPG and LNG, as well as Bulk cargoes at the International Waters-OPL (Off Port Limit) of a minimum 6NM from the Greek Territorial waters.

NAFTOMAR is a pioneer and one of the world's experts in LPG floating storage and STS operations. This expertise together with the experience of being a dedicated LPG vessel operator for almost 40 years puts Naftomar in position to assist SIGTTO whenever required, by providing technical feedback and information, as well as best practices.

Fully pressurized LPG carrier at sea

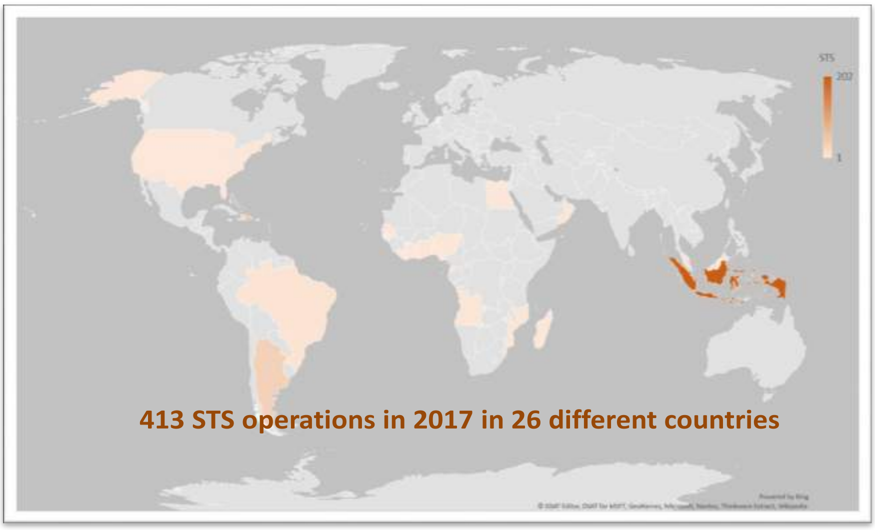
Teekay

On various occasions, Teekay has converted aging shuttle tankers into FSO units, thereby extending the life of the vessels.

Fully pressurised tankers that carry LPG to smaller gas terminals

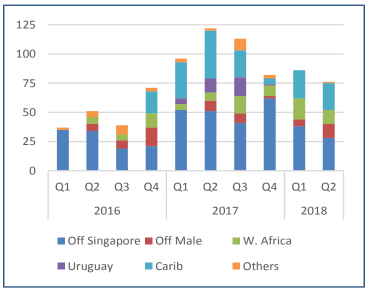
These are generally the smallest type of liquefied gas carrier afloat (up to about 5,000 cubic metres, although some are larger) and carry products at ambient temperatures in cylindrical or spherical steel pressure tanks designed to withstand pressures up to 20 bars. They are not fitted with reliquefaction plant and represent a simple cost-effective means of transporting LPGs to the smaller gas terminals.

Epic Gas Ship-to-Ship (STS) Operations Heat Map



	2014	2015	2016	2017
No. STS Ops	24	108	198	413

Operations by Region



- 162 STS operations in H1 2018
- A global demand
- Strong growth between Indonesia and Singapore
- Increased operations off Male

Today, most fully pressurised LPG carriers are fitted with two or three horizontal, cylindrical or spherical cargo tanks. However, in recent years a number of larger capacity fully-pressurized ships have been built with spherical tanks.

These were the first generation of ships to carry 3,500 m3. These ships carry the cargo in spherical or cylindrical steel tanks, designed for a working pressure of 17.5 kg/cm2. This corresponds to the vapour pressure of propane at 45oC, which is the maximum ambient temperature in which the ship is likely to operate. No means of temperature or pressure control is necessary. The tanks are generally Type C spheres and no secondary barrier is required. A double bottom is constructed for ballast water. The hold space around the cargo tanks does not need to be inerted.

Fully pressurized LPG carrier

Type 'C' tanks are normally spherical or cylindrical pressure vessels having design pressures higher than 4 barg. The cylindrical vessels may be vertically or horizontally mounted. This type of containment system is always used for semi-pressurised and fully pressurised gas carriers.

In the case of a typical fully pressurised tanker (where the cargo is carried at ambient temperature), the tanks may be designed for a maximum working pressure of about 18 barg. For a semi-pressurised tanker, the cargo tanks and associated equipment are designed for a

working pressure of approximately 5 to 7 barg and a vacuum of 0.3 barg.
The time available for bunkering, and thus loading rates, can be crucial, particularly for ro-ro/passenger vessels on tight port turnaround schedules. Bunker transfers with vapour return lines (VRLs) are quicker than those without. In this case, because the LPG in the fuelled vessel is likely be at a higher vapour pressure and temperature than the LPG in the bunkering vessel, some sort of pressure control will be required on the vapour return line.

LPG STS bunkering operations are at a relatively early stage of development and will need a regime of international safety measures to cover the interface between bunker vessels and LPG-fuelled ships – something that is still not fully developed.

The industry struggles to navigate the many standards that different authorities have issued and which need to become uniform. Notwithstanding progress towards a universal regulatory regime governing first principles, disparate LPG bunkering operations across a range of ship types and locations make possible different bunker vessel and barge designs.

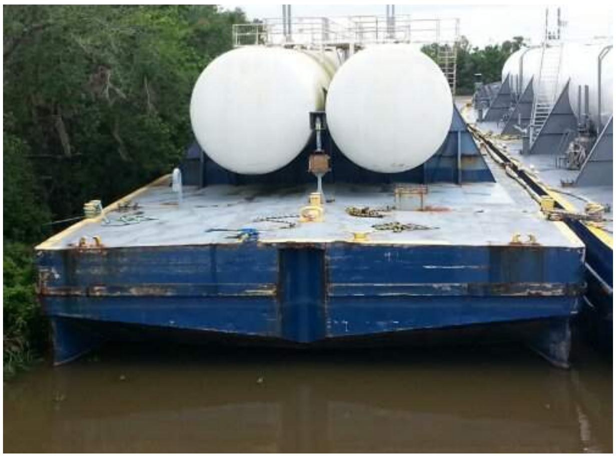
The operator of the world's largest fleet of small-size, fully pressurised (FP) gas carriers, StealthGas has embarked on an ambitious newbuilding programme to enhance its ability to distribute LPG locally to an ever-increasing number of end-users. Nine completions over the past year have boosted its in-service FP fleet to 51 vessels in the 3,500-8,000m^{3}range and further eight gas carriers, including four semi-pressurised/fully refrigerated (semi-ref) tankers of 22,000m^3. The latter quartet mark a new departure for the fleet which now covers about 20% of the fragmented global market for coastal FP LPG carriers.

Global seaborne LPG volume is expected to grow by over 6% in 2019 and surpass 100 million tonnes for the first time, primarily as a result of rising shale gas-based exports from the US Gulf. The intercontinental delivery of LPG, including from the US, is handled by a rapidly expanding fleet of 80,000m^{3}very large gas carriers (VLGCs).

3.3.4. Barge to LPG Fuelled Ship (BTS)

LPG Barges

Barge transportation is a type of ship to ship marine transportation service which provides cost effective solution owing to its ability to carry high load.



Wärtsilä Gas Solutions as an example, can provide complete cargo handling systems for unmanned LPG barges, as well as the complete ship design package for such vessels. The key to the system design is its robustness and simplicity, which enhances ease of operation. The centralised control system comes with the option to monitor cargo system wirelessly from the pusher boat during transport.

3.3.5. Ship to Ship Transfer Hubs

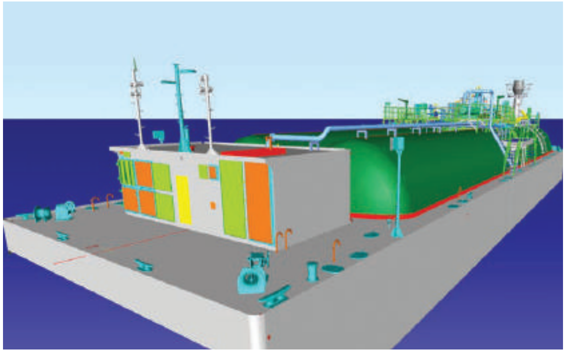
Malaysia is set to host the world's largest Ship-to-Ship (STS) transfer hub allowing higher shipping flexibility and cutting costs for shippers.

The facility will have a storage capacity of more than 9m metric tonnes of petroleum products, located on 2,800 acres of space in Johor Bahru Port waters.

The project, costing between US$150 million (S$203 million) and US$180 million, will cover an area of 1,200ha, more than three times the size of Sentosa Island. It will be built in the Strait of Johor near Tuas. The project, in Johor Baru Port waters, is billed as the "world's biggest" ship-to-ship (STS) transfer hub. It will be able to accommodate up to 30 vessels at one time. The STS Hub will utilise a state-of-the-art dolphin mooring and berthing concept which will allow the berthing of vessels for the transfer of petroleum-based products.

3.3.6. Offshore terminals for the supply of LPG

LPG consists of butane and propane and may contain minor quantities of other light hydrocarbons associated with the production of oil and gas. At ambient temperature and pressure these components exist as a gas but can be cooled



and/or pressurised to facilitate efficient liquid storage and transportation. Loading the LPG directly into or out of a tanker offshore is essential for many projects in order to capitalise on the market demand.

Case Study

By conceiving and designing an innovative floating concrete LPG terminal, Berger ABAM's offshore specialists were able to save the client millions of dollars in capital costs while providing a facility that is much more serviceable and cost-effective than traditional bulk liquid terminal construction. Although floating terminals are not an uncommon solution to LPG production in remote areas, the unique prestressed marine concrete construction developed means that the ARCO facility can remain on station in continuous operation to produce continuous cash flow over the life of the project. The periodic removal from service for dry docking for hull maintenance, typical for traditional steel hulls, is not required.

Arco Floating LPG Terminal

LPG storage and marine transportation

In the marine transportation market, LPG is typically transported by dedicated vessels suitable for carrying pressurised, semi pressurised or refrigerated LPG.

The pressurised (18-bar, ambient temperatures) or semi pressurised (5-8 bar, -10 to -20 degrees Celsius) LPG ships carry 3 – 10,000 m^3 or 10 – 30,000 m^3 respectively. Larger volumes require refrigerated transport solutions (ambient pressure, but at temperatures as low as -43 degrees Celsius for 100% propane). Fully refrigerated vessels typically have cargo volumes ranging from 35,000 m3 up to 100,000 m3. Evaluating the markets for LPG transportation world-wide, a trend is developing towards the refrigerated transport of LPG in large volumes. The offshore terminal solution is suitable for all three types of transfer. The loading/un-loading cycle, including the mooring and departure procedures, can usually be achieved in about a day.

Over the past four decades Single Point Mooring (SPM) technology applications have become a preferred method of cargo transfer from tankers to shore and vice versa. SPM technology has proven its reliability and cost effectiveness. In particular, near isolated coastlines, in areas where natural harbours are scarce or where the costs of constructing harbours and jetty structures are prohibitive.

The offshore terminal consists of a mooring and fluid transfer system (SPM), connected by means of a subsea pipeline to the LPG storage facility onshore. The SPM mooring system enables the vessel to freely weathervane in response to the wind, wave and current conditions. The pipeline (single or dual) may be several kilometres long, depending on local bathymetry, vessel characteristics and the operating philosophy of the onshore terminal. Transfer of propane and/or butane at refrigerated or semi-pressurised conditions through the fluid transfer system may require the use of insulated pipelines to prevent the LPG from warming due to the environment The insulation ensures that the products are kept at the temperature agreed upon between the terminal operator and the shipping company.

Advantages of SPM based offshore terminals

- SPM terminals offer a practical solution with a number of advantages. Congested harbours can be relieved and the difficulties and expense of upgrading quaysides and jetties can be overcome, particularly where any combination of larger vessels, limited water depth and rapidly changing weather conditions are prevalent. The SPM based terminal also allows very high availability and workability through its capacity to adapt to the environmental conditions.
- LPG consists of butane and propane and may contain minor quantities of other light hydrocarbons associated with the production of oil and gas. At ambient temperature and pressure these components exist as a gas but can be cooled and/or pressurised to facilitate efficient liquid storage and transportation. Loading the LPG directly into or out of a tanker offshore is essential for many projects in order to capitalise on the market demand.

3.3.7. Assessment of Main LPG Bunkering Options

	Ship to Ship Bunkering	**Truck to Ship Bunkering**	**LPG terminal to Ship bunkering via pipeline**	**LPG terminal to Ship bunkering via bunker vessels**
Investment Costs	LPG Bunkering equipment	LPG Bunkering equipment.	LPG Bunkering equipment	LPG Bunkering equipment
	Bunkering Vessels	Tank Trucks including filling station	Land based storage tanks	Bunkering vessels
	License costs/Safety measures/Training of personnel	License costs/Safety measures/Training of personnel	License costs/Safety measures/Training of personnel	License costs/Safety measures/Training of personnel
	Installation of quay (optional)	Installation of quay (optional)	Installation of quay (optional)	Installation of quay (optional) Land based storage tanks
Operational Costs	Operational costs of Bunker vessel	Operational costs of tank truck	Operational costs of pipeline	Operational costs of bunker vessel
	LPG terminal take out fee	LPG terminal take out fee	LPG terminal take out fee	LPG terminal take out fee
	Transhipment costs of import hub	Transhipment costs of import hub	Transhipment costs of import hub	Transhipment costs of import hub

3.4. Main Bunkering Hubs

Singapore, Rotterdam, Fujairah and Houston are the world's top four major bunkering hubs. Other key global bunkering ports include **Antwerp, Hong Kong, Gibraltar, Panama and Los Angeles/Long Beach**.

Just six countries are responsible for almost 60% of global bunker sales[7]. Even though there are approximately 400 major bunkering ports in the world, most of the demand is concentrated in a few strategic ports.

- **Rotterdam**, the biggest port in Europe, is the third largest bunkering port with annual sales of around 10.5 million MT.
- **Hong Kong and Antwerp** complete the world's top five bunkering ports by volume, with annual sales of 7.4 million MT and 6.5 million MT respectively.
- Other important ports include **Busan (South Korea), Gibraltar, Panama, Algeciras (Spain), Los Angeles/Long Beach (US) and Shanghai (China)**

In all the above hubs, it is possible LPG to be provided as bunker fuel.

7 World Oil Outlook

3.5. Current LPG Port Terminal Infrastructure

Because of the large interest in the use of LPG as fuel in the domestic, Autogas and industrial sector, including marine transportation, a number of projects for supplying LPG and supporting the infrastructure have been announced.
LPG can effectively be supplied as a bunker fuel to vessels using existing facilities such as terminals and refineries, saving

on initial costs to develop infrastructure. **There are likely to be more than 1,000 such facilities that have pressurised LPG storage tanks around the world**. It is typically easier to liquefy LPG than LNG, making it more economical and easier to handle as a bunker fuel.

Main LPG import/export terminals

Country	Location	Number of Terminals
Singapore	Banyan Terminal on Jurong Island	
		1
USA	Targa, Galena Park Texas	
	Enterprise, Houston Texas	
	Petrogas Ferndale Terminal, Ferndale, Wash	
	DCP Partners Chesapeake Terminal, Chesapeake	
	Sunoco Logistics Partners, Marcus Hook	
	Sunoco Mariner South, Nederland Texas	
	Enterprise Expansions, Houston Texas	
	Occidental Petroleum Corp., Ingleside, Texas	
		8
Argentina	Puerto Galvan, Bahia Blanca	
		1
UAE, Fujairah	Port of Hamriyah	
Netherlands	Antwerp	
		1
Netherlands	Rotterdam (3 terminals)	
		3
Spain	Algeciras	
		1
Hong Kong		
South Korea	Busan	

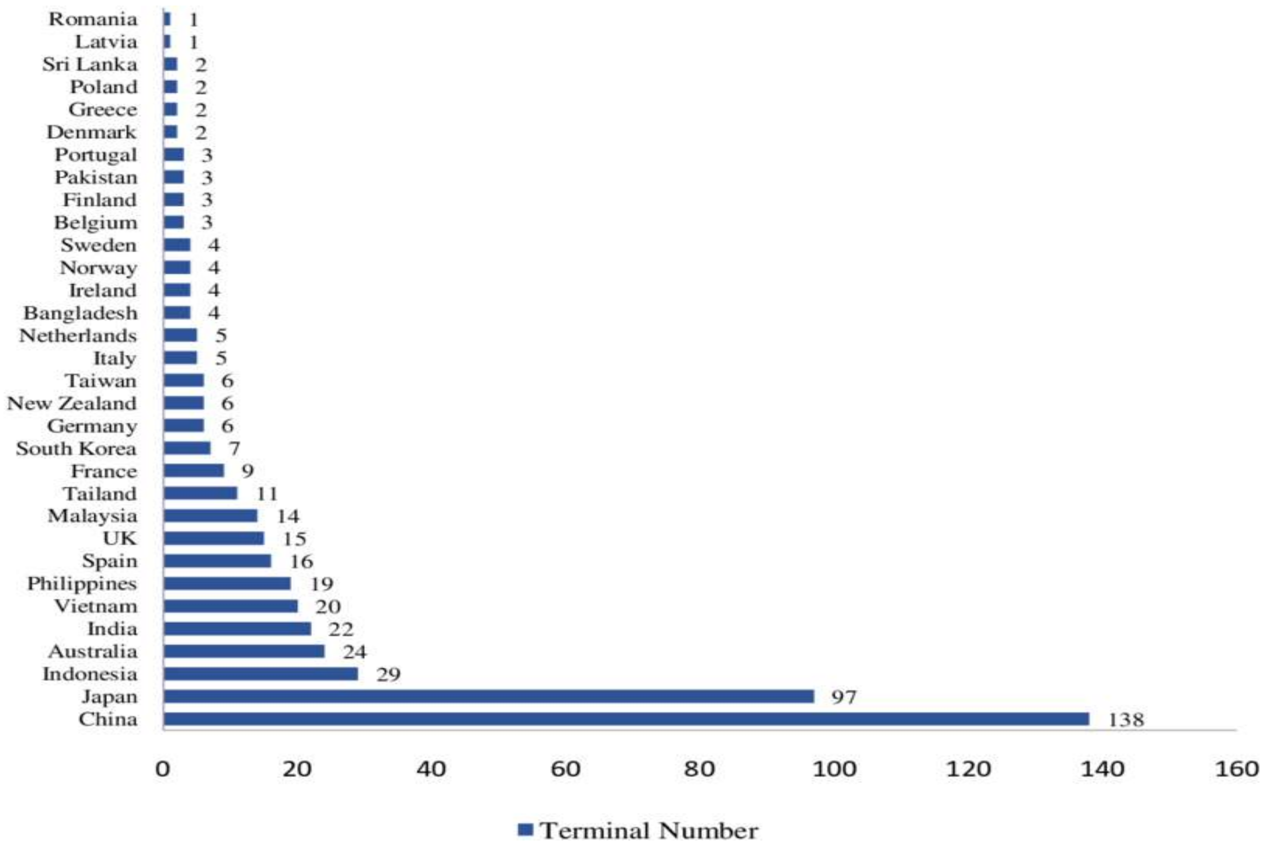
		1
Los Angeles/Long Beach		
		1
Panama		
Gibraltar	Gibraltar	
		1
Other ports		
Africa	Saldanha	
	Richard Bay	
		2
Australia	Port Bonython	
		1
Kazakhstan	Kuryk port	
		1
Malaysia	Port Klang	
		1
Sri Lanka	Hambantota International Port	
		1
Japan/China		
	Tohoku Oil Co., Ltd., Sendai Kobe, China	
	Kashima Oil Co., Ltd., Kashima	
	Kyokuto Petroleum Industries, Ltd, Ichihara	
	Tokyo Electric Power Co., Inc. Anegasaki	
	Tokyo Gas Co., Ltd. Sodegaura	
	Japan Energy Corp. Kawasaki	
	Kyodo Oil Ltd Kawasaki	
	Maruzen Oil Co. Ltd Sakal	
	General Gas Co Ltd Sakal	
	Tokyo Gas Co., Ltd. Ohgishima	
	Idemitsu Kosan Co., Ltd. Aichi	
	Tonen General Sekiyu K.K. Sakai	
	Sakai LPG Terminal Co., Ltd. Sakai	
	Iwatani International Corp. Sakai	
	Sumitomo Metal Industries Ltd Wakayama	
	Mitsubishi Corporation Kobe	
	Chugoku Electric Power Co Inc Sendal	
	Kobe steel Ltd Kakogawa	
	Nikko LPG Co., Ltd. Mizushima	
	Zen-noh Fuel Terminal Corp. Sakaide	
	Tohoku Oil Co Ltd Sendai	
	Iwatani & Co Ltd Sakal	
	Namikata Terminal Co., Ltd. Namikata	
	Continental Grain Co./Shanghai Petrochemical Shanghai	
	BP Ningbo Huadong LPG Co., Ltd. Ningbo	

	Nippon Mining Co Ltd Mitzushima	
	Kashima LPG Joint Stockpiling Co., Ltd. Kashima	
	Japan Oil, Gas and Metals National Corporation Fukushima	
	Oita LPG Joint Stockpiling Co., Ltd. Oita	
	Japan Oil, Gas and Metals National Corporation Namikata	
	Japan Oil, Gas and Metals National Corporation Mizushima	
	Japan Oil, Gas and Metals National Corporation Kashima	
	Japan Oil, Gas and Metals National Corporation Kurashiki	
		34
India	Kochi	
	Haldia	
	Mumbai	
	Tuticorin	
	Chennai	
		5
Indonesia	Pkl. Susa	
	Dumai (2 terminals)	
	TJ Uban	
	Panjang	
	Tg Priok	
	Pontank	
	Eretan	
	Masplan	
	Surabaya	
	Masplan	
	Cilacap (2 terminals)	
	TT. Manggis	
	Banjarmasin	
	Makassar	
	Bosowa	
	Natuna	
	Bontang	
	Santan	
	Balilpapan	
	Balongan	
	Palembang	
	Jabung	
		24
Brunei	Bintulu	
		1

Black Sea	Odessa	
	Taman	
	Ilyichevsk	
	Kerch	
		3
Europe		
Belgium	Antwerp	
		1
Croatia	Ploce	
		1
Denmark	Fredericia	
	Kalundborg	
		2
Finland	Hamina	
	Porvoo	
	Tornio	
		3
France	Ambes	
	Brest	
	Donges	
	Dunkirk	
	Gargenville	
	Lavera (2 terminals)	
	Le Havre	
	Petit-Couronne/Rouen	
		9
Germany	Brunsbuttel	
	Duisburg	
	Emden	
	Karlsruhe	
	Krefeld	
	Mannheim	
		6
Greece	Aspropyrgos	
		1
Italy	Brindisi	
	Livorno	
	Naples	
	Porto Levante	
	Ravenna	
		5
Ireland	Cork (2 terminals)	
	Drogheda	
	Dublin	
		4
Latvia	Riga	

		1
Netherlands	Flushing	
	Terneuzen	
		2
Norway	Kaarstoe (2 terminals)	
	Mongstad	
	Rafne	
		4
Poland	Gdansk	
	Gdynia	2
Portugal	Leixoes	
	Sines (2 terminals)	3
Romania	Constanta	
		3
	Tileagd	
		2
Spain ,	Alicante	
	Bilbao	
	Barcelona	
	Cartagena	
	Gibraltar	
	Gijon	
	Huelva (2 terminals)	
	Mallorca	
	La Coruna	
	Malaga	
	Sevilla	
	Tarragona	
	Tenerife	
	Valencia	
		15
Sweden	Gothenburg	
	Karlshamn	
	Stegnunsund	
	Sundsvall	
		4
Turkey	Alanya Aytemiz	
	Dörtyol Aygaz/Ipragaz Terminal	
	Dörtyol Milangaz Terminal	
	Dörtyol Petgaz Terminal	
	Dörtyol Yeniyurt Terminal	
	Tüpras Aliaga Refinery	
	Milangaz Aliaga terminal	
	Tüpras Tutunciftlik Refinery	
	Yarımca Milangaz Terminal	
	Marmara Ereglisi Butangaz Terminal	
	Mossmoran	
	Pembroke	
	Sullom Voe	
	Teesside (2 terminals)	
		15

Number of LPG terminals



Source: Argus

3.6. Global LPG Floating Storage Overview

LPG Floating Storage Units (FSUs) are used for STS transfer, ensuring supply and demand chains are met with no storage depletion. After a flood of U.S. exports into Asia, the market is awash with LPG and supplies are being stored in ships anchored off main ports such as Singapore.
Most of these ships are sit off a port but in international waters, and preferably as close to a grouping of ports.

LPG FSUs:

- Enable customers to resolve product shortages
- Address the problems associated with longer voyages
- Gain access to new sources of supply
- Deals with price fluctuations

The emerging glut, the latest product to be hit by oversupply, comes amid a wave of supplies from the United States, where LPG is a by-product of fracking.

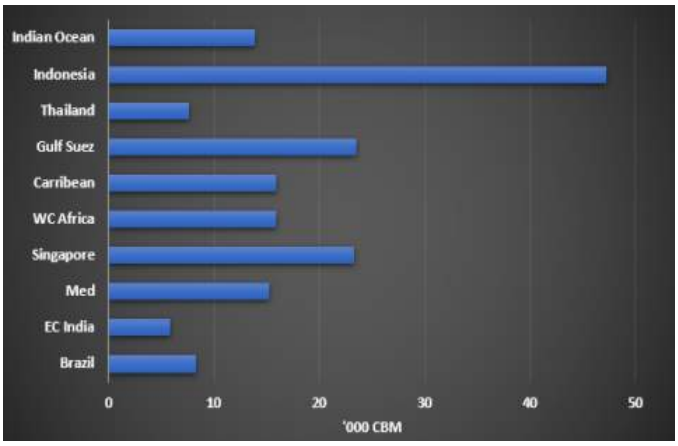
The FSV usually has a fixed monthly cost, normally the time charter rate. It consumes bunkers for keeping the cargo cold, warming it up and providing energy to all the moving parts.

Currently there are around 25 ships performing some type of floating storage operation. There are a number of reasons that come to mind for putting a “Floater” in place, the main one being to penetrate a growing market where imports are restricted to smaller storages, and berths that can only accept small pressurized ships. It is costlier to move from a small ship import facility to one that can directly receive VLGCs.

Probably the biggest cluster of floaters can be found off the main import areas of **Jakarta and Surabaya**. Pertamina still have 6 floaters; “Clipper” built 1992, “Gas Komodo” built 1991, “Pertamina Gas 1” built 2013, “Pertamina Gas 2” built 2014, “Rubra” built 2001 and “SC Commander” built 1991. The producer Suasa Benua has “Petrostar” built 1979, permanently positioned in Jabung collecting cargo for loading other ships to serve the Indonesian market.

The next big operator of floaters is Siam Gas, the public company out of **Thailand** with big LPG downstream interests in China and South East Asia. They have two ships off Thailand in Phuket, “Athena” built 1996 and in Sriracha, “Ming Zhu” built 1987. They break bulk, loading smaller ships for the regional trades into Vietnam and East Thailand in the South China Sea and for Bangladesh and East Thailand in the west. Siam Gas also operate 2 in Nipah, close to **Singapore**, “Ming Long” built 1992 and “Ming Ming” built 1991.

Vitol have teamed up with BW Gas, taking the “BW Nice” on time-charter, a 2003 built Large Gas Carrier (LGC – usually 20,000 CBM smaller than a VLGC) to load small ships and move them into **Bangladesh**.

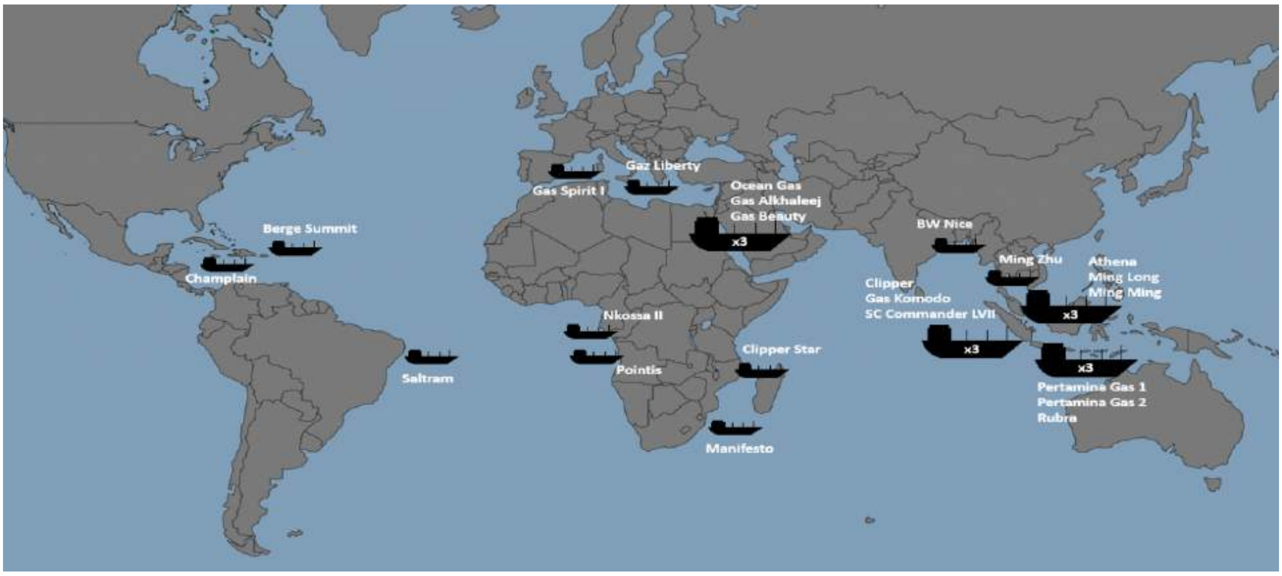


Energy Trading Analytics International

In **Egypt**, AMPTC are currently handling the floating storage operations with three ships, “Gas Alkhaleej” built 2008, Ocean Gas also 2008, and “Gas Beauty 1” built 1982. Benelux also operate Gas Spirit 1 in the Eastern Med.

Naftomar operates “Gaz Liberty” built 1997, after selling “Gas Supplier”. They position the vessel off **Crete** serving the eastern Mediterranean, including their own **Lebanese** terminal.

In East Africa, Geogas and Petredec operate floaters for the small ship receivers on the mainland and the islands. Petredec have “Manifesto” built 2013, with Geogas’s “Champlain” built 2016, also holding fort off **Madagascar.**



Energy Trading Analytics International

On the **WC of Africa**, Sonangol have a time charter ship, "Piontis" built 2016, that receives production and then re-supplies it back into Angola but is also used for trading small ships in the East Africa region. Both Vitol and Geogas have VLGCs lifting in Nigeria and Bioko, where they do perform ship-to-ship operations to cover demand into Ghana, Ivory Coast and other countries set up for small pressurised imports.

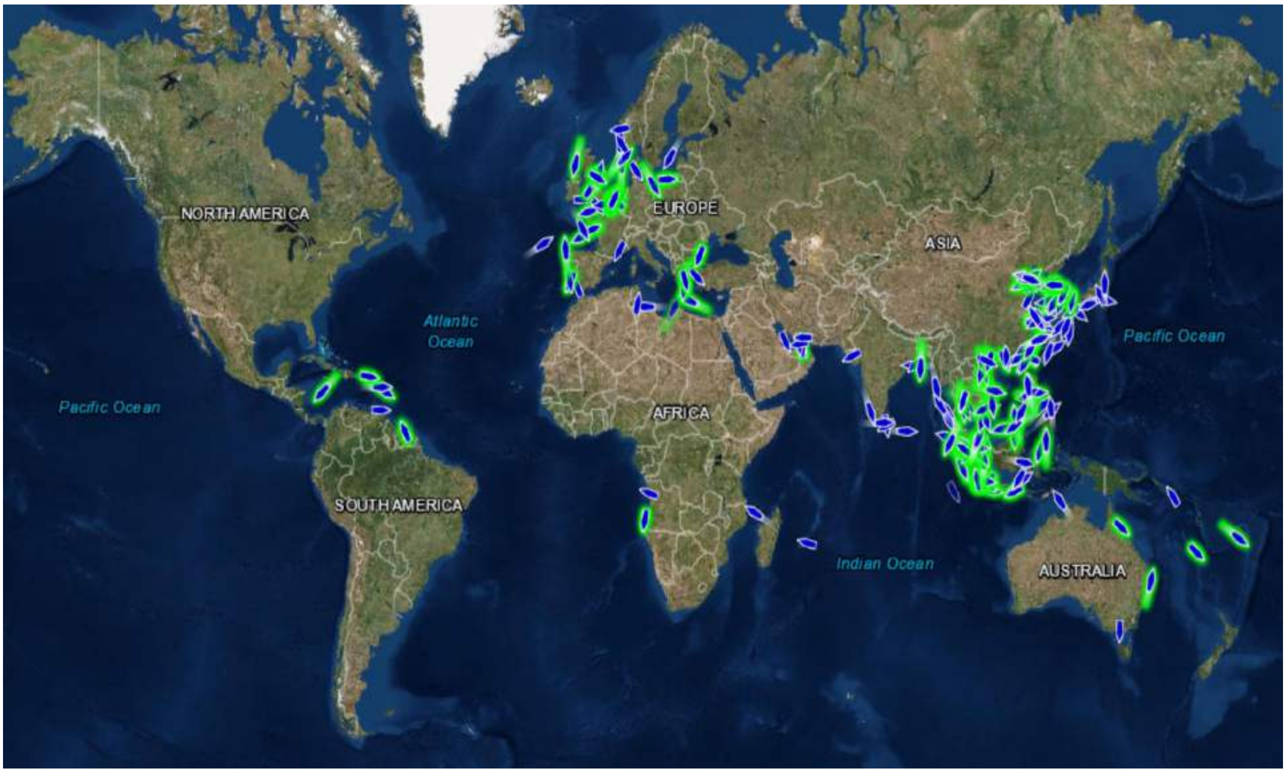
In **South America**, Petredec have time chartered "Saltram" built 2015 to Petrobras and positioned her off Suape to break bulk to smaller pressurised ships. Vitol have the "Berge Summit" built 1990, in the Caribbean off St Croix, where she feeds LPG to the US Virgin Isles electrical power generation programme, having switched to LPG back in 2013. Geogas also operate a floater in the **Caribbean** the "Clipper Star.

3.7. Small LPG Pressurized Ships Overview

Pressure fleet profile and presence
LPG pressurised vessels ranging from 3,500 to 11,000 CBM provide transportation services for LPG to many of the world's largest oil majors, refineries, trading houses and other ships. It is an increasing market.

The maps below show an indicative presence of small LPG ships in different places around the world.

3,000/4,000/5,000/6,000cbm: the largest sector, with the majority in the East.

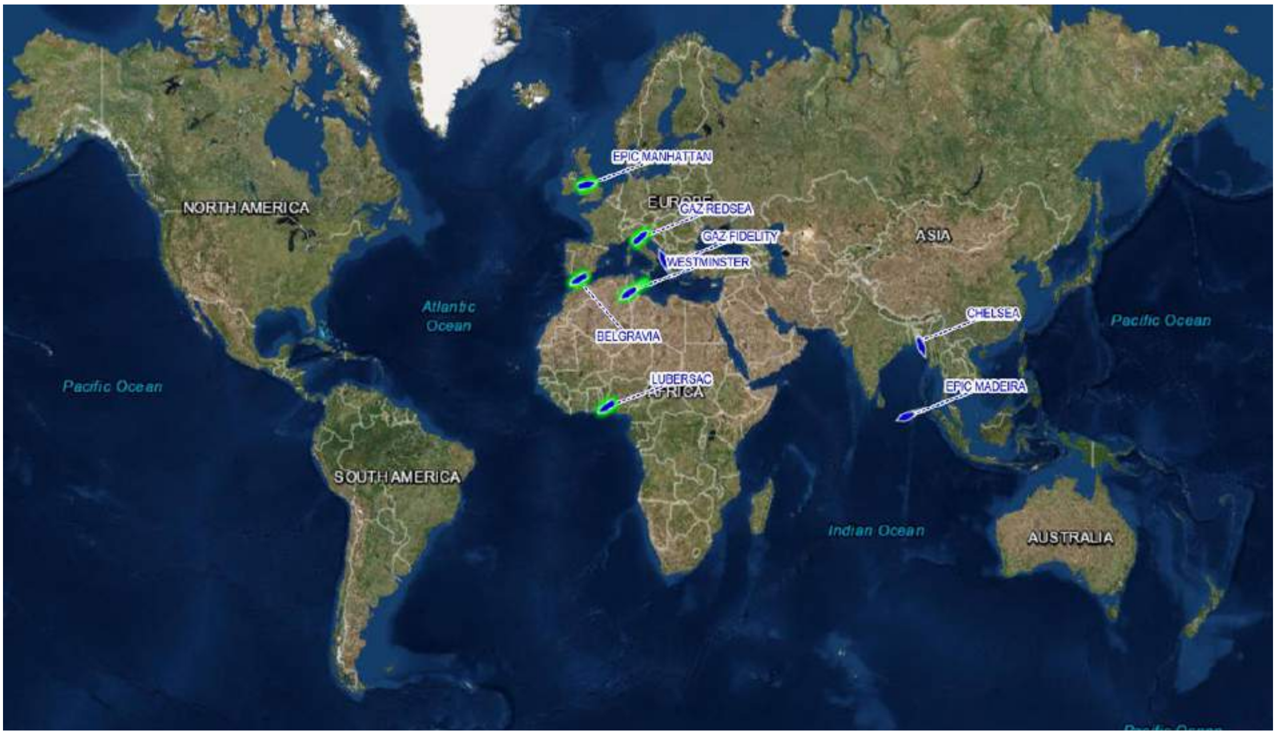


Source: IHS Market Intelligence Network, Epic Gas

7,000cbm: 30 vessels West of Suez, 18 (and growing) in the East

Source: IHS Market Intelligence Network, Epic Gas

8,000/9,000cbm: 8 vessels predominantly in the West, but opportunities in the East



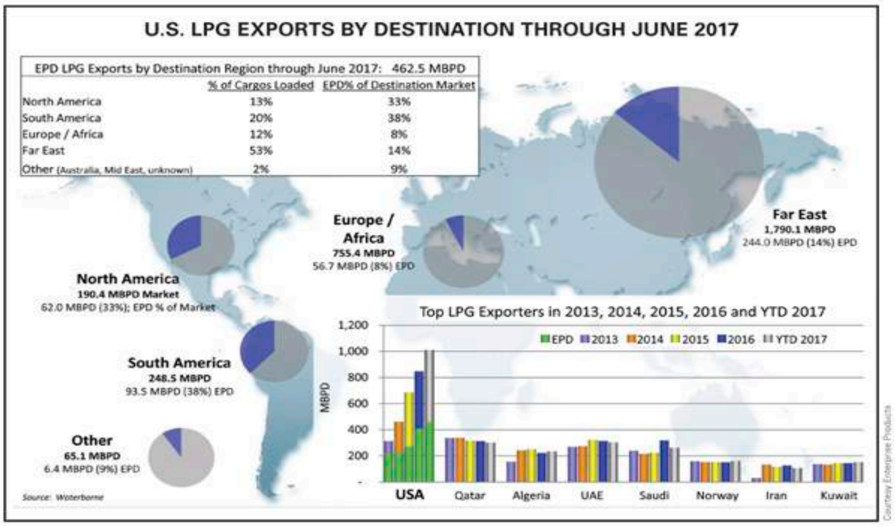
Source: IHS Market Intelligence Network, Epic Gas

11,000/13,000cbm: 22 vessels with a growing presence in East of Suez

Source: IHS Market Intelligence Network, Epic Gas

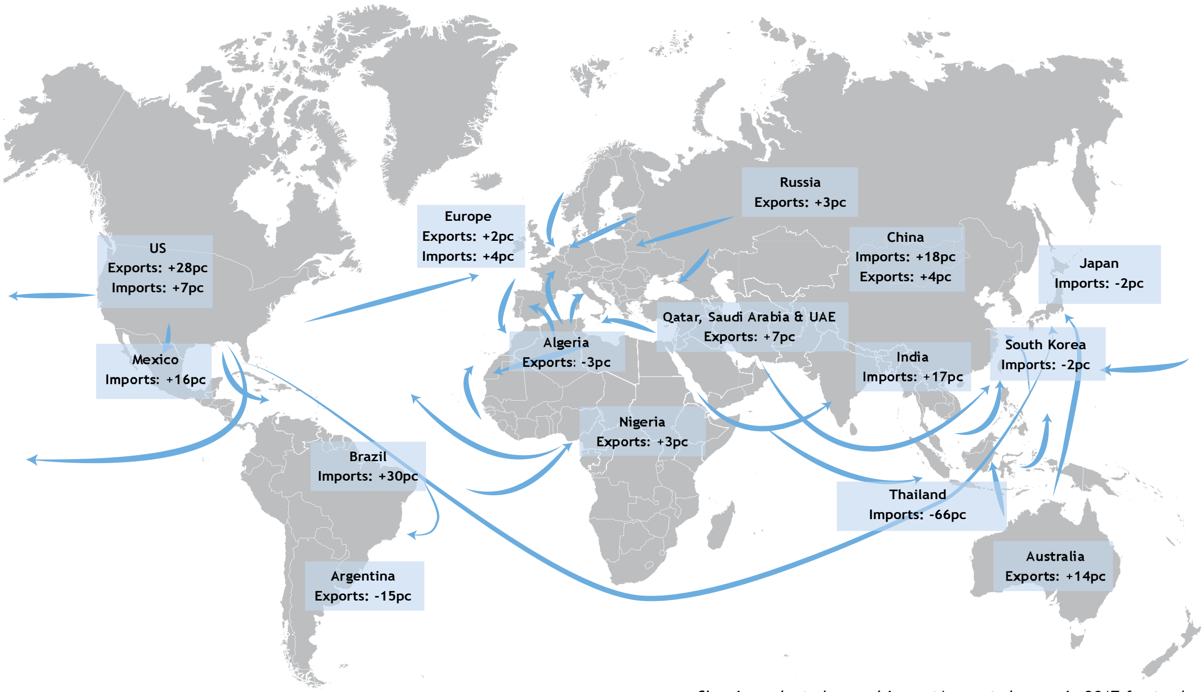
3.8. Major International Trade Routes

USA is the world's leading exporter of LPG as many developing countries transition to the more efficient and cleaner fuel. The World Health Organization reports that nearly three billion people cook and heat their homes using agricultural waste, firewood, charcoal, and animal dung, collectively known along with other fuels as biomass. The resulting indoor pollution is estimated to cause about four million premature deaths each year, along with severe deforestation and other environmental degradation, which is incentivising governments to encourage the switch to LPG.

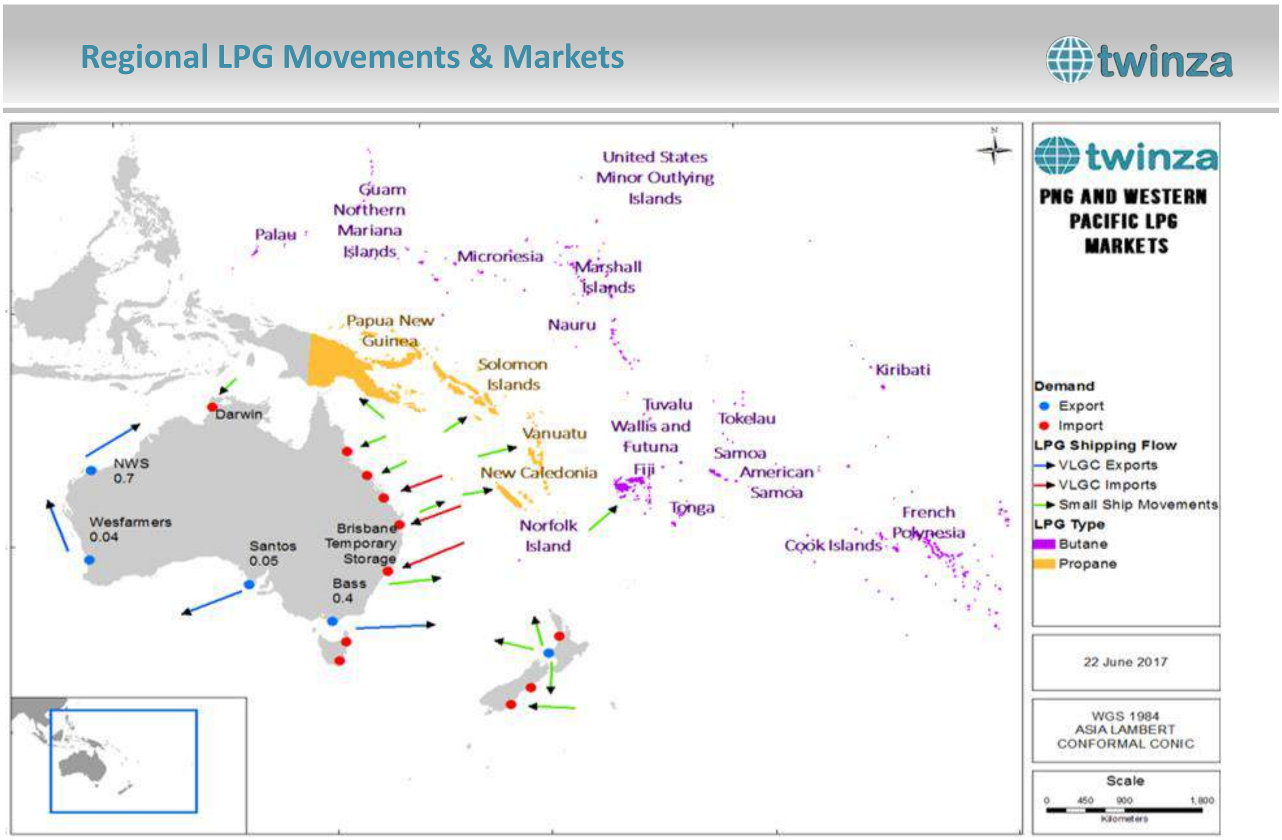


A larger factor driving demand is China's burgeoning petrochemical sector and Japan's and South Korea's eagerness to source LPG from their American ally, this in order to boost supply security and diversification. Further, the Asia-Pacific region is coming off a three-year period during which LPG demand increased 230,000 bbl/d annually, according to ESAI Energy.

Regional LPG Trade Flows

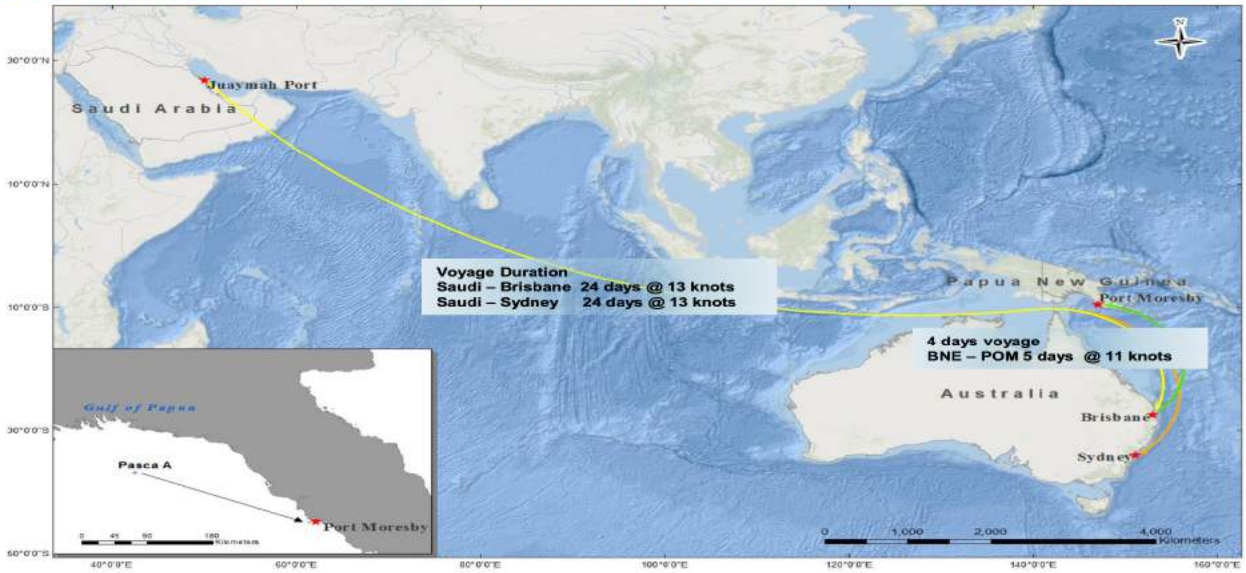


— Showing selected annual import/export changes in 2017 for trade



- **Pacific Region mostly supplied via pressure ships out of Brisbane & Sydney**
- **Market is > 30,000 metric tons per annum Propane and ~ 50,000 metric tons per annum Butane**

LPG Supply from PNG (Pasca A field) Reduces Delivery time to Regional Markets



Regionally supplied LPG from PNG reduces delivery time to regional markets by at least 30 days

- **Savings in related transport and port costs**

Source: Twinza Oil

LPG exports will exceed 50% of supply by 2019[8]

Chinese LPG demand, primarily from the residential sector, could increase by 250,000 bbl/d through 2022, largely due to the availability of U.S. supplies.[9] Chinese petrochemical demand is also expected to grow India's LPG demand could increase by 350,000 bbl/d until 2022 as the South Asian nation's Ujjwala program adds more than 100 million new residential LPG connections through 2019.

LPG exports are largely waterborne and are typically transported on specialized vessels that use refrigeration to maintain cargos in a liquid state, which allows a greater volume to be carried. The biggest very large gas carriers, or VLGCs, hold from 60,000 to 85,000 cubic meters, the equivalent of 375,000 to 530,000 barrels. The June 2016 expansion of the Panama Canal now accommodates VLGCs, cutting the journey time from the Gulf Coast to Japan almost by half and reducing the cost of exports to Asia.

India's LPG imports are expected to rebound over the second half of this year and next for a 10% annual increase. LPG production is not rising at the same pace as consumption, so imports will go up by at least 10%. India is one of the biggest buyers of butane in Asia, and the butane-propane mix that makes up the national consumption is now about even, compared to 60% butane and 40% propane earlier.

China stands as the number one importer, and China and Japan are major destinations for USA LPG, whereas direct imports by India of U.S. product have yet to emerge. Meanwhile, China's LPG demand is expected to continue growing, driven by strong petrochemical and industrial consumption, but at a slower rate because fewer propane dehydrogenation (PDH) plants are scheduled.

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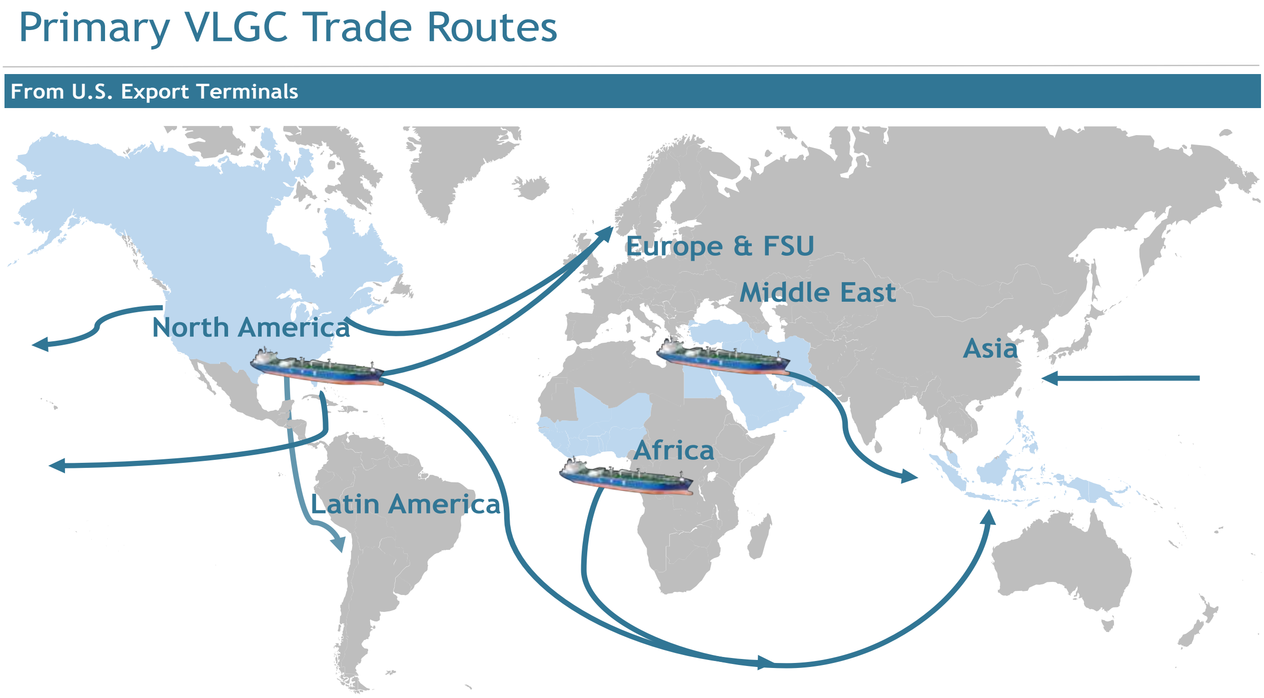
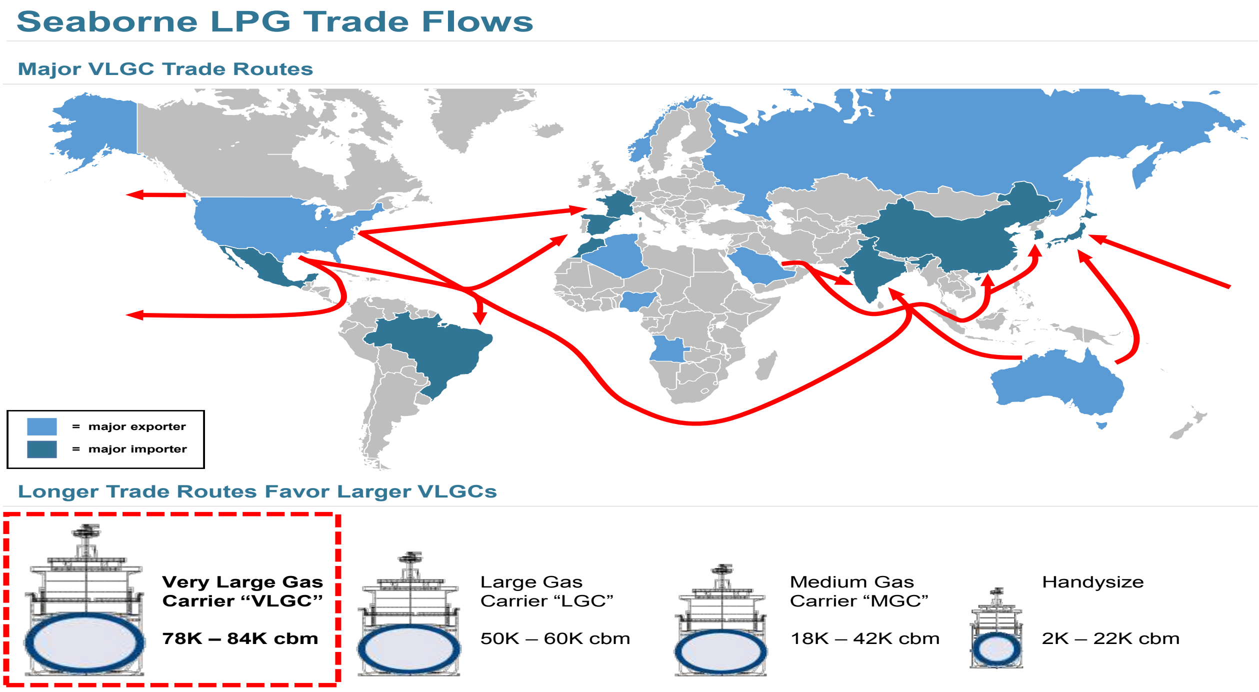
[8] ICF
[9] IEA

Global LPG demand growth continuing to be led by Asia and the Middle East, adding that while residential/commercial demand is growing steadily, chemicals demand is growing faster. Roughly half of world demand is in five countries: China, India, Japan, Saudi Arabia, and the USA. China and India are the major drivers of global demand growth. China's LPG demand growth will be a mixture of residential/commercial and chemical end uses. India's demand growth will be nearly all for residential/commercial uses. Saudi Arabia's demand is dominated by chemicals. Japan's demand is likely to decline, driven by a gradual fading in residential/commercial demand.

Finally, USA must export propane because domestic demand cannot keep up with shale-based production, even at lower oil prices. And U.S. butane exports will also increase as domestic demand is saturated and export terminal capacity becomes available.





3.9. Regulatory Issues

International rules and regulations

When a port plans to provide LPG bunkering service, it must take into account the following rules, guidelines and recommendations:

- The International Maritime Organization (IMO) is the specialised agency acting on behalf of the United Nations (UN). IMO has the responsibility for international improvement of maritime pollution and safety standards (IMO 2008b).
- IMO - IGC Code: Standard base rules for gas carrier including LPG bunker ships, but without requirements for LPG transfer systems.
- IMO - IGF Code: Standard base rules for ships using low-flashpoint fuels (as LPG) and which are not covered by the IGC Code. Still not in force, but IMO resolution MSC.285(86) (dated 1.12.2013) serves as interim guideline.

For the two ships involved in the bunkering operation there are two set of rules:

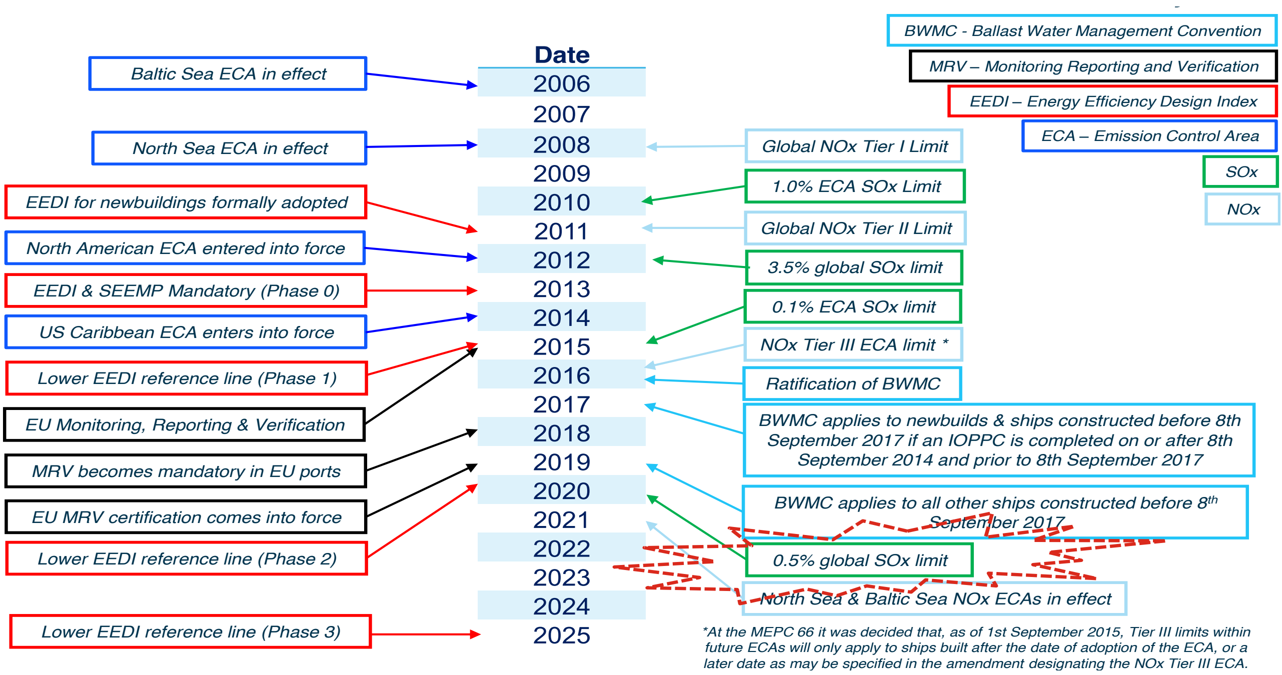
- IMO IGC Code – (International Gas Code), Rules for the bunker ship.
- IMO IGF Interim guidelines – (International Gas Fuel), Rules for the receiving ship. The IMO IGC Code is the international regulation for gas carriers and will therefore be valid for the bunker ship. For the receiving vessel, the ship using LPG as bunker fuel, the IGF guidelines are the regulations to be considered.
- Ship to Ship bunkering of LPG is a form of LPG transfer and therefore SIGGTO, Society of International Gas Tanker & terminal operators Ltd, guidelines must be considered. Though the SIGTTO guidelines are focused on large scale
- LPG transfer from LPG carriers, many of the aspects could be applied to LPG bunkering. If the bunker scenario includes transfer of both LPG and diesel (pilot fuel) from one ship to another, SIGGTO as well as the OCIMF, Oil Companies International Maritime Forum, guidelines need to be followed.

Classification societies

More or less all well-known classification societies started to released their guidelines and recommendations for LPG bunkering based on the below mentioned international rules and regulations:

- BV: Guidelines on LNG Bunkering-Guidance Note NI618DTR00E.
- DNVGL-RP-0006: 2014-01 Recommended Practice - Development and operation of liquefied natural gas bunkering facilities ISO/Industry standards/Organisations.
- ISO/TC 67/WG 10 PT1 -> OGP Draft 118683 -> EN 1474.
- EN 1474 -1/-2/-3: Design and testing of transfer arms/hoses.
- SIGTTO, OCIMF, SGMF, etc. released their guidelines, covering operational and/or safety aspects to a wide extend.
- SIGTTO, OCIMF: - Guidelines for LNG transfer and Port Operation- Guidelines for oil transfer, ship-to-ship oil bunker procedures.
- SIGTTO: LNG Transfer Arms Manifold Draining, Purging and Disconnection Procedure.
- SGMF guide: Gas as a marine fuel an introductory guide.
- SGMF: LNG Bunkering Procedures - Safety Guidelines, EU/National/Local port regulations, Flag state and port authorities normally would like to be involved in risk assessments.

Regulatory framework for ship emissions



Source: Clarksons

Besides MARPOL Annex VI, various other regulations additionally aim to stimulate the use of alternative fuels in shipping. The European Renewable Energy Directive for example demands all EU countries to ensure that at least 10% of their transport fuels come from renewable sources by 2020. Though this directive has left a limited mark on the marine fuel sector, it has led to an increased uptake of biofuels for road transport. Another important regulation is the EU LNG Bunkering Regulation, which obliges all member ports of the so called TEN-T core network to provide LNG fuelling facilities by the end of 2025, and inland ports by the end of 2030. Furthermore, a number of international rules also aim to improve the energy efficiency of ships, such as the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP). One missing measure that would significantly speed up the adoption of alternative fuels is a global or regional market-based measure for GHG emissions in shipping. Though the EU has outlined various ambitions, there is still no carbon tax for shipping, neither is the shipping sector included in the EU Emissions Trading System.

The EU has stipulated the ambition to realise a modal shift to move respectively 30% and 50% of European road freight travelling over 300 km towards rail or waterborne transport by 2030 and 2050. Another goal is to reduce EU CO2 emissions from maritime transport by 40% by 2050 compared to 2005 levels.

Dedicated forms of financing specifically directed to speeding up the development of the alternative fuel market are also available, especially on a European level. Subsidies for R&D in alternative fuels and dedicated lending through the European investment bank are increasing in popularity. Most notable is the EU Program for the development of Motorways of the Sea (MoS) within the Trans-European Transport Network (TEN-T**).** This program provides capital for the development of green bunkering infrastructure along EU coastline. In 2018, a seven-million-euro European subsidy was granted to The Dutch firm Port-Liner for the construction of six of the eleven 100% electric barge ships which it will add to its fleet. Shipping range is between 15 and 35 hours, depending on the size of the lithium battery and ship. A striking fact is that loading capacity is 8% higher than fuel oil vessels of comparable size.

3.10. Bunkering and Safety

Historically, carriage and the transfer of maritime LPG have an outstanding safety record, and the safeguards associated with LPG import/export terminals are proven. While LPG bunkering involves far lower quantities and transfer rates when compared to import/exports, many of the safeguards are applied to ensure safety.

LPG has a higher density than air and any spillage will collect in lower spaces, requiring a different approach to leak detection and ventilation in the case of leaks. LPG is a low-flash-point liquid, and when used in a high-fire-risk space of the ship with a constant personnel presence, like in the engine room, a double-walled pipeline must be used as secondary containment. Hydrocarbon detectors will detect any leakage and contain the fuel within the secondary containment before it reaches areas where humans are present. Double-walled pipelines must be used below the deck line. The auto ignition temperature for LPG (490°C) is lower than for LNG (580°C), which may require a lower surface.

Presently, most regulations apply to LPG transported as a cargo rather than as fuel. Although LPG in its liquid form cannot burn or explode, if spilled it can form a pool on the water. Since LPG boils at ambient temperature, a vapour cloud would then be formed in the air and easily dispersed with the winds. While the risk of fire or explosion increases in confined spaces like a ship or building, there is not sufficient evidence of LPG fire or explosion in open spaces.
Terminals must ensure safety for the protection of local communities where the receiving terminals are based. In other words, they must clearly understand the hazards of LPG bunkering. Four risk scenarios can be considered:

- Leaks from LPG pumps, pipes, hoses and tanks
- Accidental disconnection of hoses
- Overfilling and or overpressure in tanks; this can happen if the operator keeps filling the tank when it is already full
- External impact which can be originated if the cargo accidentally falls over the bunkering equipment, collision between ships or collision between the road tanker and bunkering equipment.

At least four layers of protection are required:

- Primary containment
- Secondary containment
- Safeguard systems
- Safety or separation distances

Safety distances should be considered along the planning phase because will necessarily imply more land and consequently costs. The European Union together with other LNG related associations are working towards the harmonisation of a methodology for risk assessment which will be based on the ISO standards. Remarkable is the agreement signed by the ports of Antwerp, Zeebrugge and Singapore to harmonise LNG bunkering standards.

The development of any new technology and especially so if the new technology involves engines and equipment, machinery, vehicles that use LPG as a fuel, requires uppermost attention and consideration of safety implications. LPG, same as any other engine fuel can be entirely safe as long as the equipment is designed correctly with all safety aspects taken into account and the operation is equally carried out in the same manner. New technologies require thorough assessment of all potential safety risks.

LPG tanks, fuel lines, and carburetion components must meet strict specifications. As an example, LPG tanks used in vehicles are constructed to the highest standards, are many times more as puncture-resistant as petrol tanks and they are tested to four times their standard operating pressure. Built-in safety devices automatically shut off fuel lines in case of an accident.

Safety of LPG Bunkering in Ports

Leakage of LPG during LPG bunkering can pose several hazards. Extreme care must be taken to ensure that LPG does not drip or spill onto ship hulls or decking because it could lead to brittle fracture, seriously damaging a ship or bunkering barge.

LPG spilled onto water can pose a more serious hazard as it will rapidly and continuously vaporize into natural gas, which could ignite. The resulting “pool fire” would spread as the LPG spill expands away from its source and continues evaporating. A pool fire is intense, far hotter and burning far more rapidly than oil or gasoline fires, and it cannot be extinguished; all the LPG must be consumed before it goes out. Because an LPG pool fire is so hot, its thermal radiation may injure people and damage vessels or property a considerable distance from the fire itself. Many experts agree that a large pool fire, especially on water, is the most serious LPG hazard.

Leaks of LPG can also release LPG into a port area and cause fires or explosions. While a bunkering barge or a vessel using LPG for fuel contains far less LPG than large LPG carriers, LPG spills in bunkering operations could still be a significant concern.

Risks associated with bunkering LPG are complicated in ports seeking to engage in “simultaneous operations” during the bunkering process. Simultaneous operations entail loading and unloading cargo and personnel from a ship, maintenance, and other logistical operations performed while a ship is bunkering.

A collection of safeguards, which were developed based on a thorough evaluation of LPG- related regulations, codes, and standards, including the International Association of Oil and Gas Producers (OGP) and ISO’s Waterfront Facilities Handling Liquefied Hazardous Gas, the National Fire Protection Association’s (NFPA’s) 59A – Standard for the Production, Storage, and Handling of LPG - Waterfront Facilities Handling Liquefied Hazardous Gas, are indicative mentioned below. Collectively, they are designed to prevent accidental releases of LPG and mitigate the consequences if releases do occur. Each safeguard plays a unique role. Some are designed to prevent certain initiating events from occurring, others are designed to mitigate certain types of consequences, and some play a role in both prevention and mitigation.

Prevention Safeguards

Standardised connections at bunkering station to prevent inadvertent leaks or hose disconnects.
Independent high-level alarms on vessel fuel tanks to alert operators prior to tank overfill. Note: Separate high-level switch initiates emergency shutdown (ESD).

Periodic inspection and testing of equipment prior to bunkering to ensure system is functional and there are no leaks.
Periodic testing and certification of hoses to ensure hoses and fittings will not leak or disconnect during transfer.

Ship-to-shore communications to ensure information can be shared between parties involved in bunkering (e.g., person in charge, ship crew, truck driver).

Constant supervision by persons in charge on both vessel and facility.

Mitigation Characteristics

- Controls and/or prohibitions on simultaneous operations reduces likelihood of dropping cargo or stores on LPG transfer equipment or external impact from vehicles or equipment involved in simultaneous operations. Reduces crew/passenger population in hazardous areas and reduces potential ignition sources from simultaneous operations.
- ESD system reduces likelihood of overfilling vessel fuel tanks through automatic shutdown on high level and also reduces the amount of LPG release by closing valves and stopping transfer pumps during hazardous conditions.
- Restricted vehicle traffic reduces likelihood of vehicle impact with bunkering equipment and population in hazardous area near vessel and limits possible ignition sources in the case of an LNG release.
- Comprehensive bunkering procedures addresses a broad array of prevention topics including: operating conditions, required equipment, safety, training, communications, mooring, connection, transfer, lifting, and disconnection.
- Operator training covers a broad array of prevention topics to ensure that operators are trained in safe work practices and understand all tasks for normal and non-routine operation and to ensure that operators are aware of LPG hazards and are trained for emergency operations.
- Accepted ship design and construction standards
- Ship design standards, safe ship arrangements, manufacture, workmanship, and testing to minimize probability of LPG leaks, to mitigate impacts on people and property in case of an LPG release (e.g., fire safety equipment, electrical classification, ventilation).
- Regulated Navigation Areas reduces likelihood of vessel impact with bunkering equipment and population in hazardous area near vessel and limits possible ignition sources in the case of an LPG release.
- Warning signs reduce likelihood of external impact with bunkering equipment and population in hazardous area near vessel and limits ignition sources near bunkering operations to reduce likelihood of a fire if a release of LNG occurs.
- Breakaway couplings on hose connections designed to minimise LNG releases in the case of excessive movement (e.g., truck drive-away, vessel drifting away).
- Hazardous area classification near bunkering operations where accidental releases could occur to limit ignition sources.
- Personal protective equipment to protect operators from exposure to LPG and fire hazards.
- Firefighting equipment, including dry chemical and water deluge systems, to mitigate fire damage if LPG release ignites.
- Spark-proof tools to reduce likelihood of ignition if LPG is released.
- Ship emergency response plans with procedures to guide crew in addressing various LPG-related hazards.
- Local emergency response plans with procedures to guide first responders in addressing various LPG-related hazards.

3.11. Bunkering and Training

Training of personnel in new technologies, new equipment and particularly in areas where safety is of prime concern is key. This is the case when LPG is introduced as a new alternative fuel in any equipment and operations. Adequate training is a prerequisite before any such new engine and equipment is put into service.

3.12. Main Stakeholders

Important stakeholders for the development of an LPG bunkering infrastructure include the potential investors in LPG terminals, i.e.:

- Terminal Operators
- Bunker vessel operators
- Port Authorities
- Storage System Operators
- LPG supply companies

Stakeholders apart from the he shipping industry itself are also its administrations:

- Maritime administrations in Northern Europe
- The International Maritime Organization (IMO)
- The EU including the European Maritime Safety Organisation (IMO)
- Standardization organisations as SIGGTO and ISO
- Classification societies;

Other stakeholders are:

- National port administrations
- Energy authorities
- Land-based safety authorities
- Planning agencies
- Municipalities around the potential terminals
- The general public

Finally banks and financial institutions play central roles while the establishment of an infrastructure is connected to long-term investments.

LPG markets are gradually shifting into increasingly open markets due the possible transportation of LPG, which implies that new business models and model contract agreements may develop. In this context, it is important that the suppliers understand the prerequisites of the ship owners when turning to them.

One key aspect is the interaction between different stakeholders and their different perspectives on the infrastructure development. It is important to interact regularly around the challenge of transferring the shipping industry into a more environmentally concerned activity. Especially when regarding such a complex issue as the establishment of a new infrastructure.

3.13. Engagement of Stakeholders

Strong Involvement of all stakeholders and players is vital:

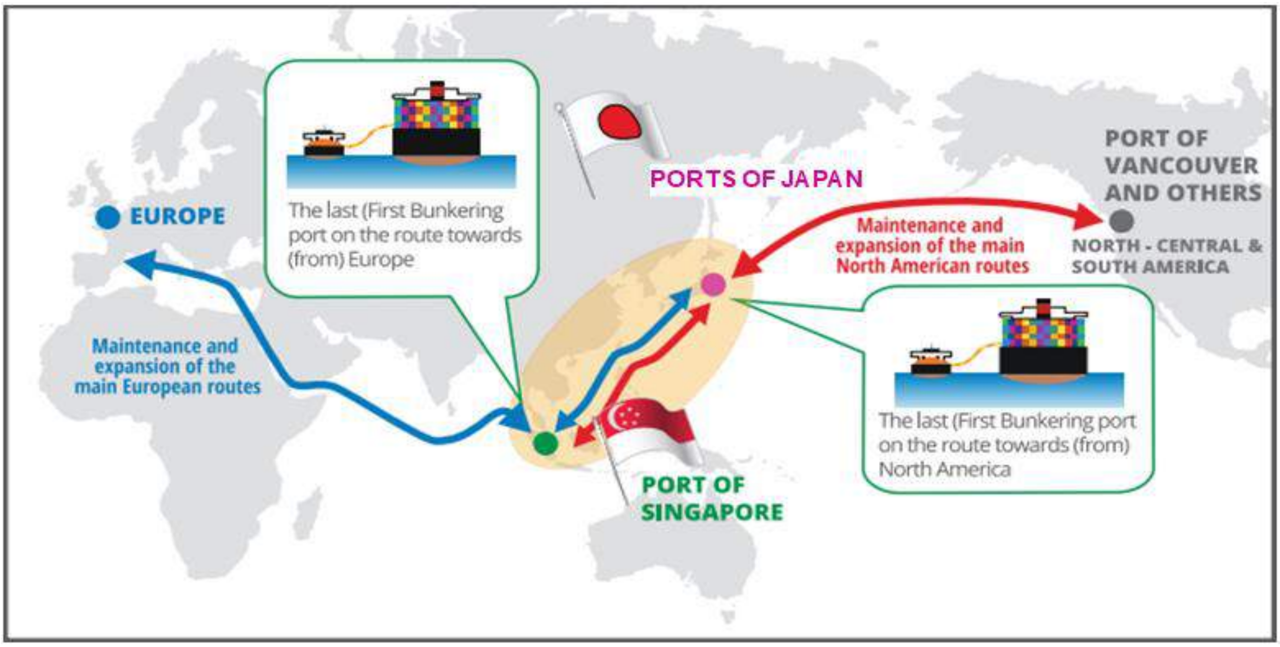
- Authorities & Ministries have to build cooperation strategies and roadmaps
- Ports & the public engagement vital
- Permitting process and understanding of successful communications is needed
- Staying updated continuously regarding international developments

Chapter Four

Roadmap

4.1. Strategic New LPG Hub Developments

Considering future scenarios, Asia could develop one dominant trading hub acting as a reference for the whole region. It would also be possible for several trading hubs to coexist in Asia, given the expected future size of the Asian market. Singapore would become a bunkering hub for Southeast Asia or Europe-bound trade, and Japan would a hub for East



Source: MLIT (2016).

Asia and North America-bound trade. By engaging in strategic cooperation, the countries aim to streamline equipment standards, qualifications required for seafarers and safety measures, which facilitate the operation of LPG-fuelled ships. While there are no harmonised standards yet, the countries involved expect to simplify the uptake of LPG as a ship fuel and contribute in developing a global market by further harmonising their standards.

There is an opportunity for Japan's ports to leverage the operational pattern of container ships by offering LPG bunkering facilities to the liner shipping companies. Specifically focusing on liner shipping, which has the advantage of fixed routes, should be done in collaboration with other ports on the traditional liner shipping routes. This will ensure that the ports "on the other end" have a similar LPG offering so that the fuel tank size could be minimised on traditional liner routes for higher profitability. Such an approach may be the easiest way for overcoming the "chicken and egg" problem that assumes that LPG demand also depends on the availability of bunkering infrastructure.

- LPG exporting countries as a whole is the largest producer and exporter of LPG. It implies that the economics of their LPG bunkering projects may differ from other countries.

- Many LPG exporting countries already have the relevant LPG infrastructure, developed first of all for large scale LPG exports. They need to make relatively lower investment only to adjust the existing infrastructure to the needs of the shipping industry, in particular to allocate specific LPG bunkering facilities.
- Many LPG exporting countries have high maritime trade volumes which paves the way for building LPG bunkering hubs in their respective countries. Moreover, some of the countries are notable for favourable geographic location in their respective regions (Middle East and North Africa, Latin America and the Caribbean, Sub-Saharan Africa, Europe) close to the major global trading routes. That may facilitate the usage of their LPG bunkering infrastructure by the largest global shipping companies.

4.1.1. Africa

LPG plant opened at Port of Saldanha

A new open-access LPG plant has been opened at the Port of Saldanha on the West Coast of South Africa and will aid in increasing the use of environmentally-friendly and affordable LPG in the national energy mix.

Sunrise Energy is a partnership between the South African private and public sectors. It is 60% owned by Mining Oil & Gas Services (MOGS), a subsidiary of Royal Bafokeng Holdings, and 31% by the Industrial Development Corporation. The facility comprises a 10.9 hectare landside terminal and waterside multi-buoy mooring connected via a three-kilometre subsea and over-land pipeline. Current Phase 1 of the terminal entails five tanks with 5, 500 tonnes of storage, allowing for a monthly capacity of 17, 500 tonnes of LPG. Phases 2 and 3 of the project will see modular expansion that will enable the terminal to meet regional LPG supply demands for the next 27 years.

Richards Bay – South Africa

Bidvest Tank Terminals and Petredec started the construction on 1 billion rand ($70 million) LPG import and storage facility in Richards Bay, which will ultimately ensure a cost-effective, reliable and safe energy source for southern Africa.

The facility will be the largest in Africa and will significantly increase the supply of LPG to South Africa and allow for exports of the fuel to neighbouring countries. South Africa currently uses approximately 400,000 tonnes of LPG annually. The Mounded LPG Facility is expected to increase this by 200,000 tonnes a year. The facility will comprise four 5,650 tonne tanks, the largest such tanks in the world, and dedicated 24-hour road tanker and railcar loading facilities will ensure a reliable supply 365 days a year on board the vessel XIN LU. The Richards Bay Mounded LPG Facility is expected to be operational in 2020.

LPG storage cylinders

Inclusion of LPG in new Kipevu Oil Terminal

Kenya in conjunction with the China Communications Construction Company is set to construct an oil terminal at the port of Mombasa; this is after the two parties signed an agreement.
According to the Kenya Ports Authority, the new terminal will see to an increase in discharge capacity over ten times, this means that the new facility will store up to 400,000 metric tonnes up from the current 35,000 tonnes. The terminal will have the capacity to handle four vessels of up to 100,000 DWT and will have a LPG line that is expected to help stabilize gas supply in the country.

Initially, construction was to be finalised by 2019 but the cancellation of an initial 2016 tender to include LPG line pushed the completion time to 2022.

The two LPG lines will run just next to the Liwatoni Fisheries Complex. The complex, which is currently under construction, is supposed to enable the docking of large fishing and patrol vessels. It is part of the government's plan to improve Kenya's capacity to gain from the global blue economy.

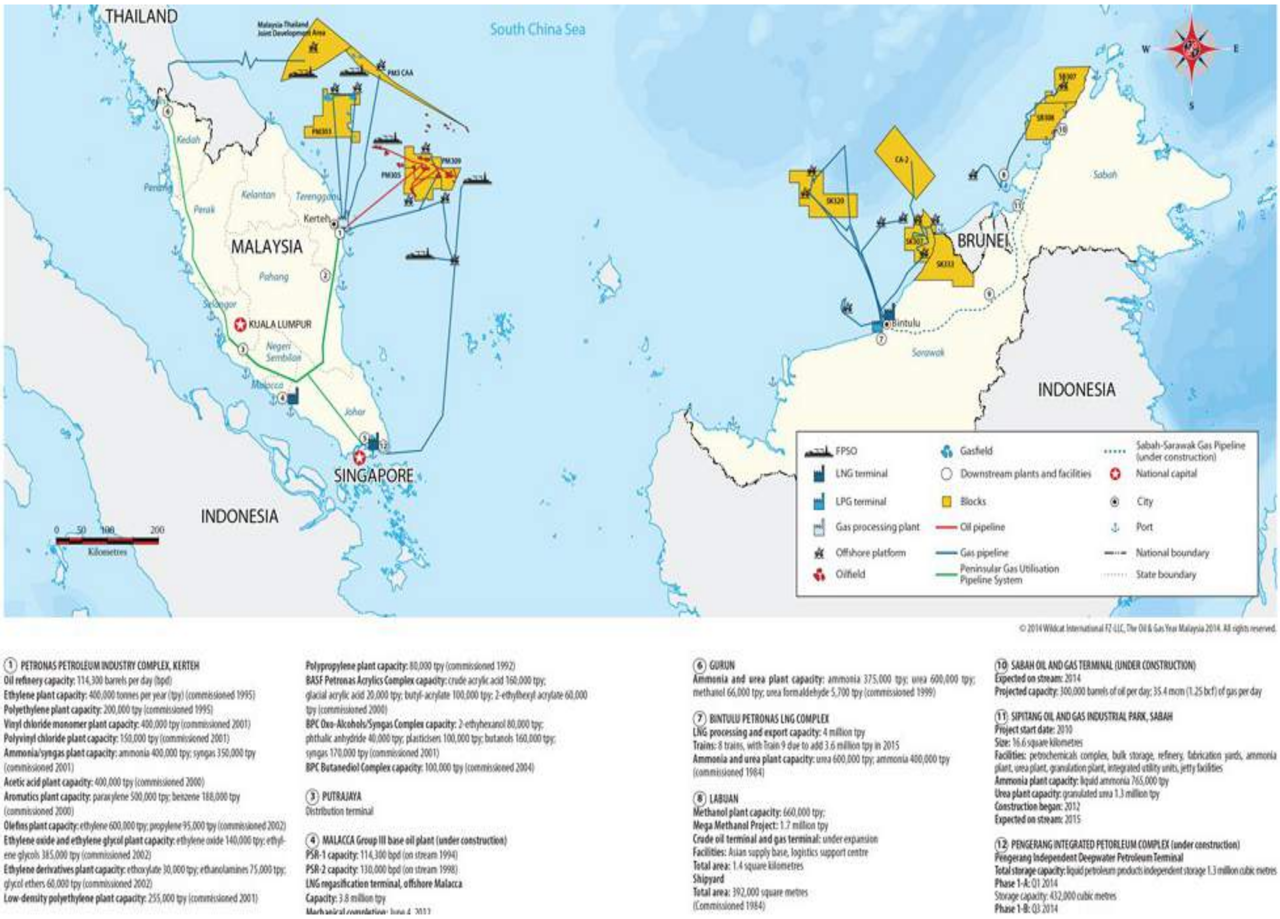
4.1.2. Asia/Pacific

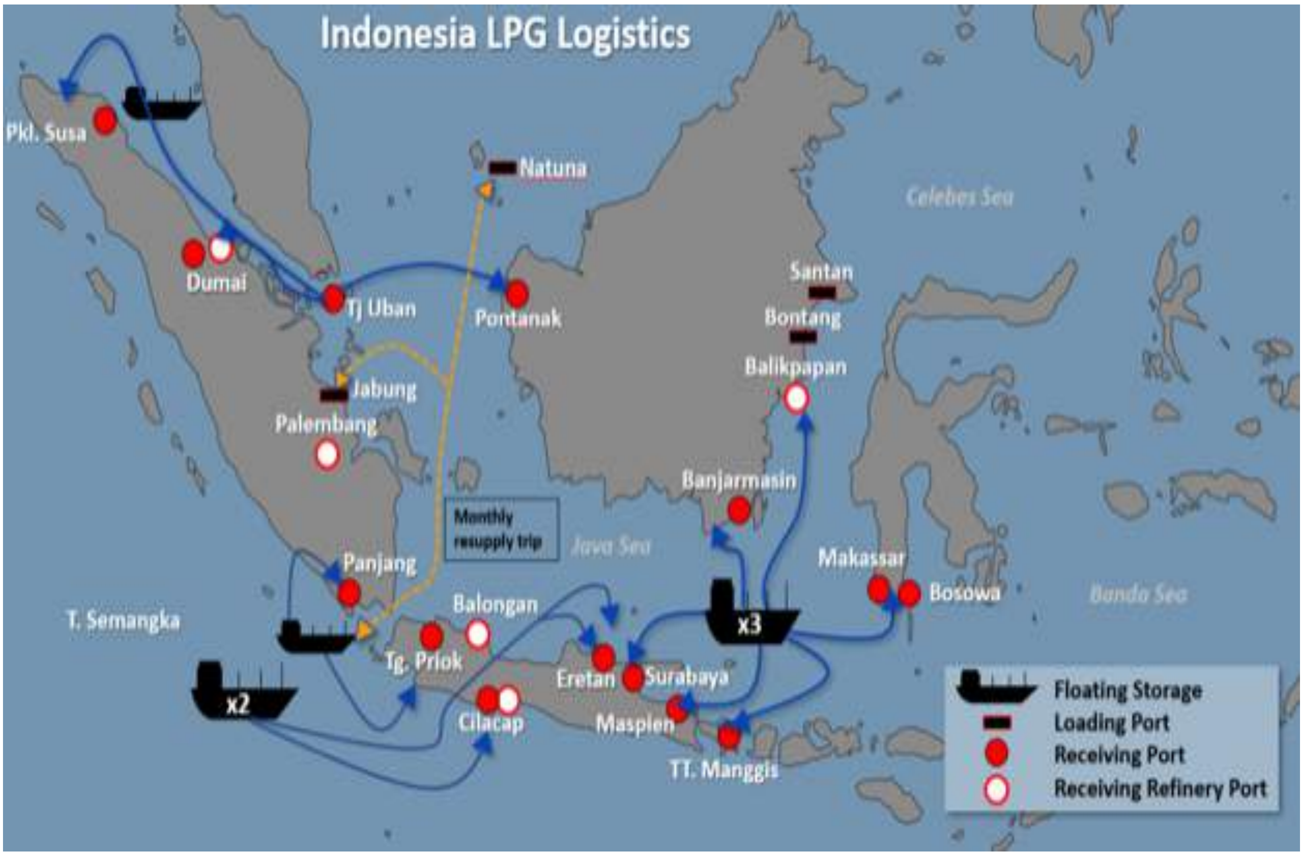
Import/Export Terminals

Equinor partners with Global Petro Storage for Malaysia LPG terminal

Norwegian oil and gas firm Equinor collaborate with storage and logistics provider Global Petro Storage to establish a terminal and storage facility for LPG in Port Klang, Malaysia. GPS will build a new 135,000m³ facility that can handle 1.5Mtpa of LPG and will exclusively provide storage services to Equinor. The new facility should be ready by early 2021. The terminal represents a foreign direct investment of 300 million USD to Malaysia.

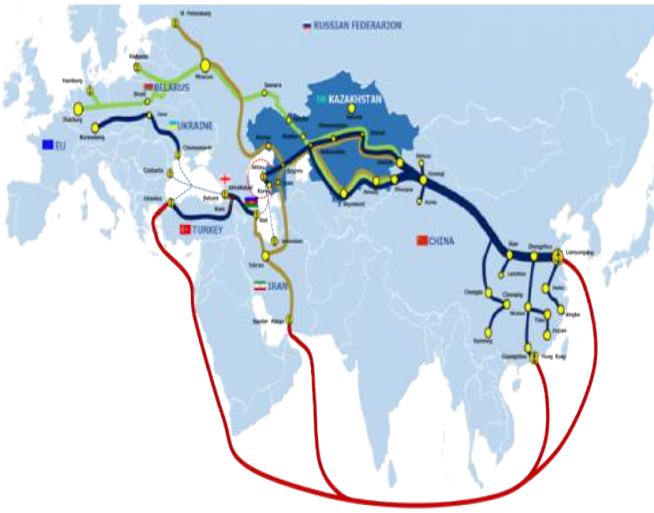
According to GPS, the terminal will have the ability to handle VLGC and pressurised LPG vessels on its jetty. The terminal and storage are also strategically located for blending and selling to other growing markets in the region. Equinor will bring LPG from multiple regions such as the North Sea and North Africa to the terminal at Port Klang to sell in Malaysia and other Asian markets, including Bangladesh, the Philippines, India, Indonesia and Vietnam. Equinor currently accounts for nearly 10% of the global waterborne LPG volumes. The terminal and storage are also strategically located for blending and selling to other growing markets in the region.


THAILAND
South China Sea
Malaysia-Thailand Joint Development Area
MALAYSIA
Kerteh
KUALA LUMPUR
SINGAPORE
INDONESIA
BRUNEI
Bintulu
Sabah
Sarawak
Kilometres
FPSO
LNG terminal
LPG terminal
Gas processing plant
Offshore platform
Oilfield
Gasfield
Downstream plants and facilities
Blocks
Oil pipeline
Gas pipeline
Peninsular Gas Utilisation Pipeline System
Sabah-Sarawak Gas Pipeline (under construction)
National capital
City
Port
National boundary
State boundary
© 2014 Wildcat International FZ-LLC, The Oil & Gas Year Malaysia 2014. All rights reserved.
(1) PETRONAS PETROLEUM INDUSTRY COMPLEX, KERTEH
Oil refinery capacity: 114,300 barrels per day (bpd)
Ethylene plant capacity: 400,000 tonnes per year (tpy) (commissioned 1995)
Polyethylene plant capacity: 200,000 tpy (commissioned 1995)
Vinyl chloride monomer plant capacity: 400,000 tpy (commissioned 2001)
Polyvinyl chloride plant capacity: 150,000 tpy (commissioned 2001)
Ammonia/syngas plant capacity: ammonia 400,000 tpy; syngas 350,000 tpy (commissioned 2001)
Acetic acid plant capacity: 400,000 tpy (commissioned 2000)
Aromatics plant capacity: paraxylene 500,000 tpy; benzene 188,000 tpy (commissioned 2000)
Olefins plant capacity: ethylene 600,000 tpy; propylene 95,000 tpy (commissioned 2002)
Ethylene oxide and ethylene glycol plant capacity: ethylene oxide 140,000 tpy; ethylene glycols 385,000 tpy (commissioned 2002)
Ethylene derivatives plant capacity: ethoxylate 30,000 tpy; ethanolamines 75,000 tpy; glycol ethers 60,000 tpy (commissioned 2002)
Low-density polyethylene plant capacity: 255,000 tpy (commissioned 2001)
Polypropylene plant capacity: 80,000 tpy (commissioned 1992)
BASF Petronas Acrylics Complex capacity: crude acrylic acid 160,000 tpy; glacial acrylic acid 20,000 tpy; butyl-acrylate 100,000 tpy; 2-ethylhexyl acrylate 60,000 tpy (commissioned 2000)
BPC Oxo-Alcohols/Syngas Complex capacity: 2-ethyhexanol 80,000 tpy; phthalic anhydride 40,000 tpy; plasticisers 100,000 tpy; butanols 160,000 tpy; syngas 170,000 tpy (commissioned 2001)
BPC Butanediol Complex capacity: 100,000 tpy (commissioned 2004)
(3) PUTRAJAYA
Distribution terminal
(4) MALACCA Group III base oil plant (under construction)
PSR-1 capacity: 114,300 bpd (on stream 1994)
PSR-2 capacity: 130,000 bpd (on stream 1998)
LNG regasification terminal, offshore Malacca
Capacity: 3.8 million tpy
(6) GURUN
Ammonia and urea plant capacity: ammonia 375,000 tpy; urea 600,000 tpy; methanol 66,000 tpy; urea formaldehyde 5,700 tpy (commissioned 1999)
(7) BINTULU PETRONAS LNG COMPLEX
LNG processing and export capacity: 4 million tpy
Trains: 8 trains, with Train 9 due to add 3.6 million tpy in 2015
Ammonia and urea plant capacity: urea 600,000 tpy; ammonia 400,000 tpy (commissioned 1984)
(8) LABUAN
Methanol plant capacity: 660,000 tpy;
Mega Methanol Project: 1.7 million tpy
Crude oil terminal and gas terminal: under expansion
Facilities: Asian supply base, logistics support centre
Total area: 1.4 square kilometres
Shipyard
Total area: 392,000 square metres
(Commissioned 1984)
(10) SABAH OIL AND GAS TERMINAL (UNDER CONSTRUCTION)
Expected on stream: 2014
Projected capacity: 300,000 barrels of oil per day; 35.4 mcm (1.25 bcf) of gas per day
(11) SIPITANG OIL AND GAS INDUSTRIAL PARK, SABAH
Project start date: 2010
Size: 16.6 square kilometres
Facilities: petrochemicals complex, bulk storage, refinery, fabrication yards, ammonia plant, urea plant, granulation plant, integrated utility units, jetty facilities
Ammonia plant capacity: liquid ammonia 765,000 tpy
Urea plant capacity: granulated urea 1.3 million tpy
Construction began: 2012
Expected on stream: 2015
(12) PENGERANG INTEGRATED PETORLEUM COMPLEX (under construction)
Pengerang Independent Deepwater Petroleum Terminal
Total storage capacity: liquid petroleum products independent storage 1.3 million cubic metres
Phase 1-A: Q1 2014
Storage capacity: 432,000 cubic metres
Phase 1-B: Q3 2014


Indonesia LPG Logistics
Pkl. Susa
Natuna
Celebes Sea
Dumai
Tj Uban
Pontanak
Santan
Bontang
Balikpapan
Jabung
Palembang
Banjarmasin
Monthly resupply trip
Java Sea
Makassar
Bosowa
Banda Sea
Panjang
T. Semangka
Balongan
x3
Tg. Priok
Eretan
Surabaya
x2
Cilacap
Maspion
TT. Manggis
Floating Storage
Loading Port
Receiving Port
Receiving Refinery Port

Kazakhstan Kuryk port

The terminal is designed for transshipment of oil, bulk oil cargo, and LPG, is located on the territory of 26 hectares, and will be equipped with two berths. The depth at the berths is 7 meters. The terminal has capacity of 300,000 tons per year.



Kochi LPG terminal - India

Indian Oil Corporation is all set to re-start construction activities at its 22 billion euro LPG import terminal-cum-pipeline project at Puthuvypeen near Kochi. The Kochi projects consists of an import terminal, multi-user liquid terminal (MULT) jetty, Kochi-Salem pipeline and the bulk LPG terminal at Palakkad with a total investment of 22 billion euro. Of this, the 2.25 billion euro jetty is ready and the company has invested another 1.6 billion euro for construction activities.

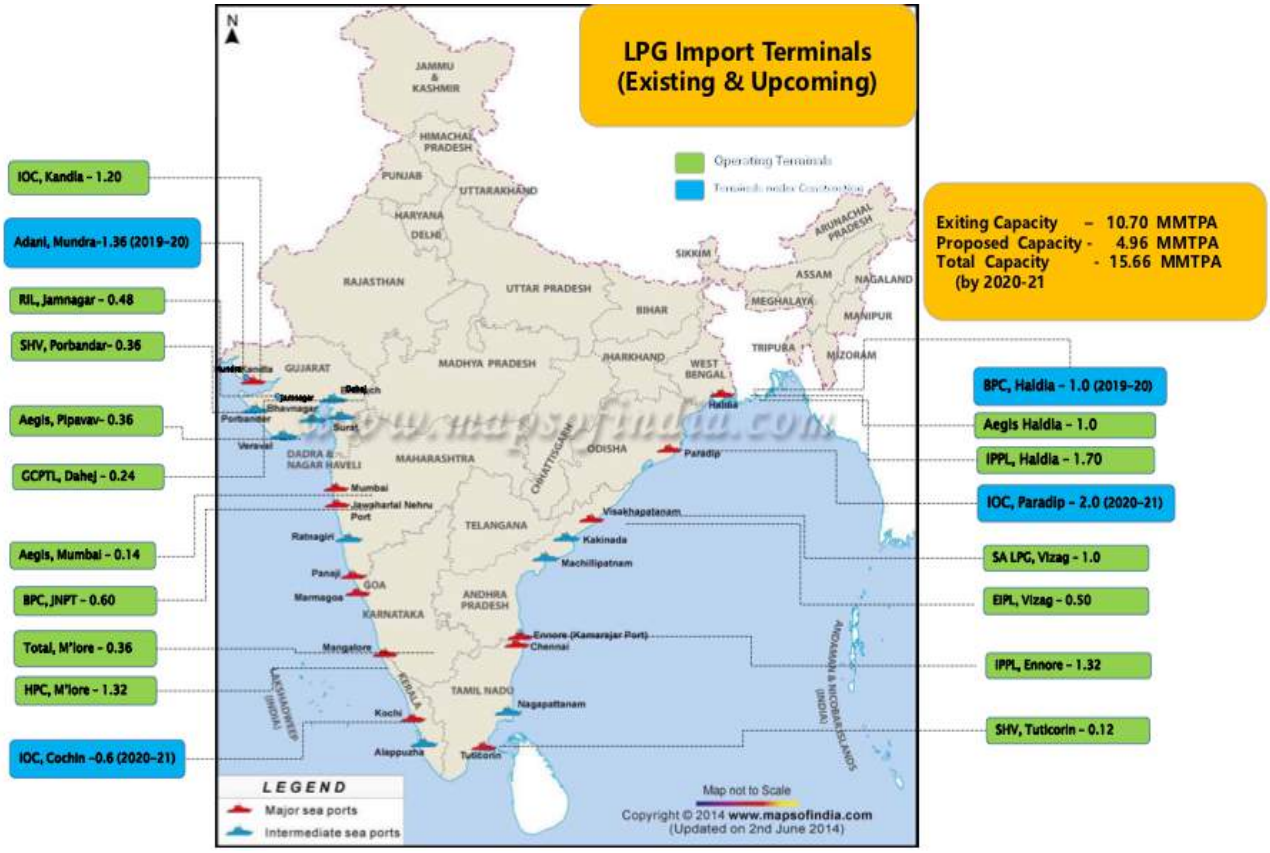
India's LPG imports expected to grow

Indian Oil Corporation aims to complete the expansion of its Gujarat refinery in Vadodara to 18 million mt/year by 2020 and the Panipat refinery capacity to 25 million mt/year by the end of fiscal 2020-21. Hindustan Petroleum Corp. Ltd. aims to almost double Visakhapatnam's capacity to 15 million mt/year by March 2020. India's big refinery project in Maharashtra, being developed by state-owned IOC, HPCL and Bharat Petroleum Corp. Ltd. will start around 2022-2023, while a HPCL project in Barmer is due by March 2023.Privately run Reliance Industries aims to raise total capacity at its Jamnagar refining complex to 100 million mt by 2030.

Major Ongoing Projects

- Up-gradation of Refineries for improving yield of LPG
- Greenfield LPG Import Facilities at Kochi (0.6 million mt/year), Paradip (2.0 million mt/year), Haldia (2.0 million mt/year) & Mundra (1.36million mt/year)

- Brownfield expansion of Kandla LPG Import facilities from 0.6 to 2.5 million mt/year



LPG hub in Mer Rouge

Petredec (Mauritius) Ltd operates a 15,000 Mt LPG storage terminal in Mer Rouge, Port Louis. It serves as a central hub for LPG supply to East Africa and the Indian Ocean islands. The jetty can accommodate the largest LPG carriers with a capacity of 84,000 cubic metres.

Sri Lanka, LPG transshipment terminal

The Laugfs LPG Terminal is an important energy infrastructure in the Indian Ocean, having strategically located amidst key international maritime trading routes connecting west to east.

With a projected annual export value of US $ 500 million, the 30,000 mt LPG terminal represents a significant investment in infrastructure development in Sri Lanka. The new LPG Transshipment facility will also serve to initiate coastal shipping services between Hambantota and Colombo ports for the first time in the country. Strategically located in close proximity to some of the largest emerging LPG markets and key international trading ports in the region, the Laugfs LPG transshipment terminal will garner multiple benefits to the regional LPG players, elevating its significance as a central LPG hub in South Asia. With tremendous opportunities to support the regional growth of the LPG industry, plans are also underway for the capacity to be extended to 45,000 mt by the completion of the second phase of the project, marking a total project investment of US $ 85 million. The Laugfs LPG terminal will operate as a central hub for LPG importing, re-exporting as well as provisioning to retailers.

4.1.3. Europe

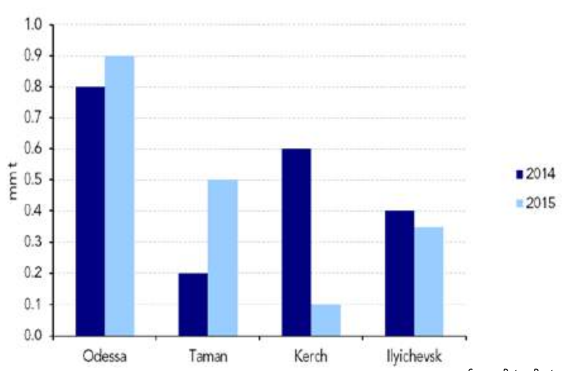
Port of Ploce becoming the main Adriatic port for ships of deep draft

VTTI, a global independent operator for energy storage and Energia Naturalis Holding (ENNA) have signed an agreement by which VTTI acquires 70% of Adriatic Tank Terminal (ATT) at the Port of Ploce, the main Adriatic port for ships of deep draft. VTTI and ENNA together will expand and manage the newly constructed terminal in the Port of Ploce. VTTI will operate additional capacity, with significant new capacity for the storage of LPG, by which will be used the latest technology. There is 60,000 m3 for storage of LPG.

It is the largest new project for the storage of liquefied petroleum gas (LPG) in the heart of the Adriatic. In the future, additional space would allow construction of the third phase, which would provide additional storage capacity of at least 100,000 m3 of petroleum products. It is one of the largest private investments in the Republic of Croatia, whose planned amount is €.135 million

Black Sea LPG terminals

Main Black Sea LPG exporting ports – 2014 vs 2015

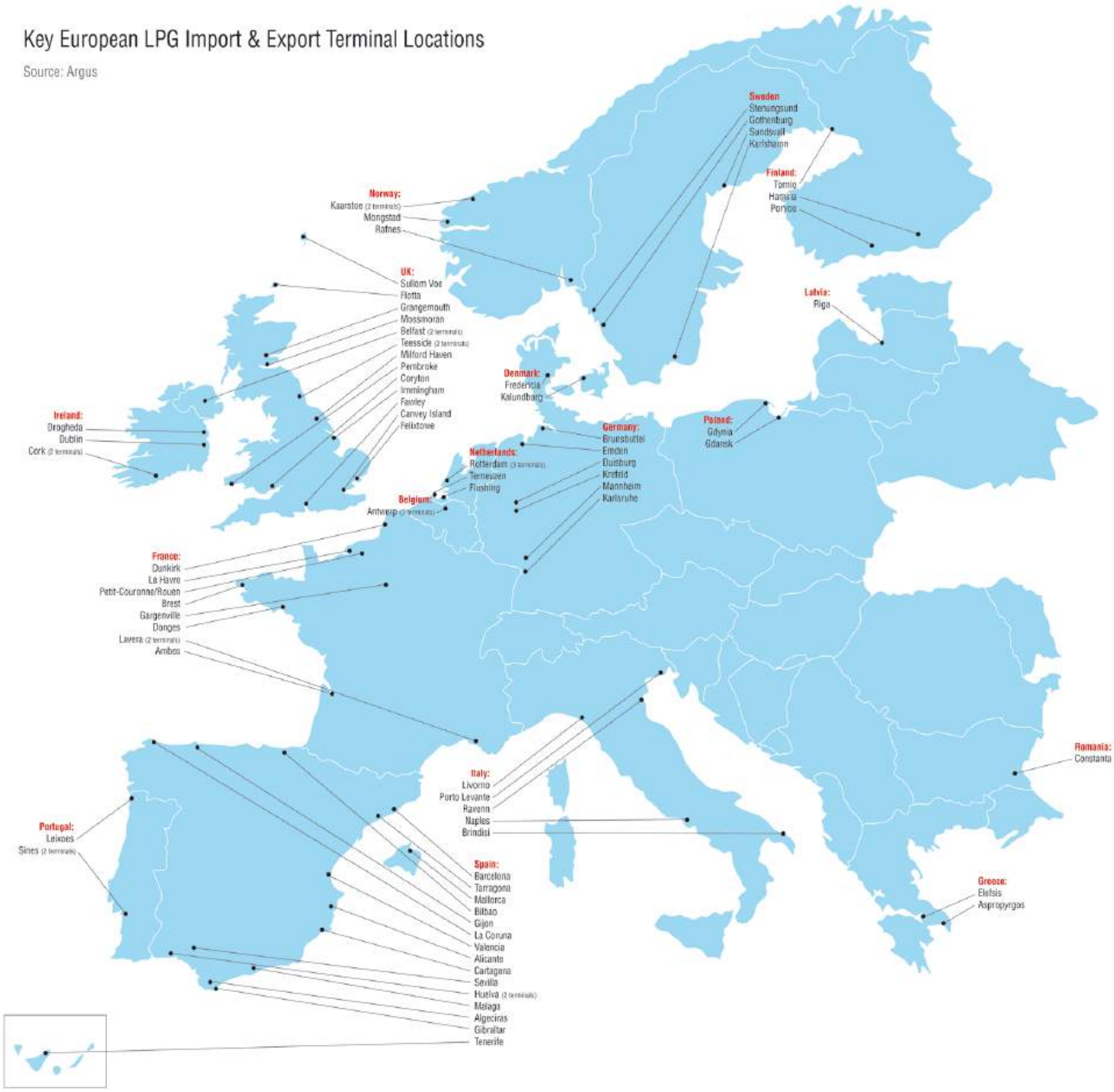


Source: Poten, Reuters

Black Sea LPG Ports

Source: Poten & Partners

Major LPG import/export terminals in Europe



▶	Belgium:	Antwerp (3 terminals) Denmark: Fredericia, Kalundborg
▶	Finland:	Hamina, Porvoo, Tornio
▶	France:	Ambes, Brest, Donges, Dunkirk, Gargenville, Lavera (2 terminals), Le Havre, Petit-Couronne/Rouen
▶	Germany:	Brunsbuttel, Duisburg, Emden, Karlsruhe, Krefeld, Mannheim
▶	Greece:	Aspropyrgos, Elefsis
▶	Italy:	Brindisi, Livorno, Naples, Porto Levante, Ravenna
▶	Ireland:	Cork (2 terminals), Drogheda, Dublin Latvia: Riga
▶	Netherlands:	Flushing, Rotterdam (3 terminals), Terneuzen Norway: Kaarstoe (2 terminals), Mongstad, Rafnes
▶	Poland:	Gdansk, Gdynia
▶	Portugal:	Leixoes, Sines (2 terminals)

- Romania: Constanta
- Spain: Algeciras, Alicante, Bilbao, Barcelona, Cartagena, Gibraltar, Gijon, Huelva (2 terminals), Mallorca, La Coruna, malaga, Sevilla, Tarragona, Tenerife, Valencia
- Sweden: Gothenburg, Karlshamn, Stegnunsund, Sundsvall
- UK: Belfast (2 terminals), Coryton, Canvey Island, Fawley, Felixtowe, Flotta, Grangemouth, Immingham, Milford Haven, Mossmoran, Pembroke, Sullom Voe, Teesside (2 terminals)

Turkey

Alanya Aytemiz New Terminal

- Maximum DWT 50000
- Max Loa 225 meters
- Max Beam 30 meters
- Depth @ Dolphin 20 meters

Other Terminals in Turkey for VLGC sizes are:

- Dörtyol Aygaz/Ipragaz Terminal
- Dörtyol Milangaz Terminal
- Dörtyol Petgaz Terminal
- Dörtyol Yeniyurt Terminal
- Tüpras Aliaga Refinery
- Milangaz Aliaga terminal
- Tüpras Tutunciftlik Refinery
- Yarımca Milangaz Terminal
- Marmara Ereglisi Butangaz Terminal

LPG terminal in Tileagd, Romania

MOL Romania has completed the construction of the LPG terminal in Tileagd, Bihor County. The investment in the new facility, covering an area of over 10,000 sqm, has exceeded 2.3 million euro. The terminal, which is perfectly operational, includes four LPG tankers with a total storage capacity of 600 cubic meters, four discharge/charge pumps connected to two compressors – designed for an annual capacity of up to 30 kton. The facility is equipped with a fully automatic, computer-controlled charging system and complies with all regulations on occupational safety and the environment.
The gas is stored in terrestrial tanks, equipped with state-of-the-art safety and protection systems, including automatic volume and temperature measuring devices, fixed fire extinguishing systems, as well as early detection and alarm sensors. The terminal is also provided with a vapor recovery unit to reduce emissions of volatile organic compounds, complying with the highest standards in the field. It is estimated that the new facility will reach annual delivery 30 kton by 2020.

4.1.4. Middle East

LPG terminal in Aqaba

The terminal can receive large oil vessels with storage capacities of up to 25,000 tonnes and has an unloading capacity of 300 metres per hour. The 23 million euro terminal project increasing the efficiency of importing LPG.

4.1.5. USA

LPG terminals that are currently operational are:

Operational Terminals	Location	Capacity (bbl/d)
▶ Targa	Galena Park Texas	289,000
▶ Enterprise	Houston Texas	249,000
▶ Petrogas Ferndale Terminal	Ferndale, Wash	30,000
▶ DCP Partners Chesapeake	Chesapeake	8,000
▶ Sunoco Logistics Partners	Marcus Hook	50,000
▶ Sunoco Mariner South	Nederland Texas	197,000
▶ Enterprise Expansions	Houston Texas	279,000
▶ Occidental Petroleum Corp.	Ingleside, Texas	80,000
▶ Phillips 66 Freeport Terminal	Freeport, Texas	144,000
▶ Sunoco Marcus Hook Expansion	Marcus Hook	175,000
▶ Altagas BC Terminal	British Columbia	38,000
▶ Sea-3 Newington	Newington	15,000
▶ Sea -3 Tampa Bay	Tampa Bay	12,000 (2020)

Source: ICF international

ORIGIN Energy opened its new LPG terminal in Paget
A state-of-the-art facility including 180 tons of storage, safer features and easier access for transport.

Targa's Galena Park export terminal can load four ships simultaneously

Enterprise Products Partners (EPP) has taken on the first-mover mantle and is the largest exporter of US LPG. The company has boosted the capacity of its Houston Ship Channel terminal in phases over the past few years to maintain its lead. The upgrade included docking facilities to load VLGCs up to 85,000m^3.

- US refiner Phillips 66 build a 6 mt/year LPG export facility alongside its Freeport oil terminal in Texas. The company expects to load 12 VLGCs per month once the new facility comes on stream.
- Occidental Petroleum, the US upstream independent, is also providing an outlet for surplus US LPG but its new Ingleside terminal will export less than its Texas counterparts. The 2.9 mt/year terminal was poised to commence operations, with shipments being handled by smaller gas carriers.

East coast liftings

- US shale plays are dotted around the country and the Marcellus and Utica deposits in the Pennsylvania and New York state area are among the largest and most prolific.
- Sunoco Logistics is the first to capitalise on the export potential of these resources. It has complemented its Nederland, Texas terminal with a new LPG and ethane export complex.
- Mariner East, on the Delaware River at Marcus Hook near Philadelphia. Like EPP's Houston terminal, Mariner East is a phased project over several years.

- Marcus Hook boasts fully refrigerated tankage for LPG and ethane and five underground NGL storage caverns.
- Some 450km to the south in Virginia, DCP Midstream has begun to load butane cargoes for export at its 235,000 tonnes per annum. Chesapeake terminal. A converted propane-import terminal, Chesapeake is expected to handle two to three export cargoes per month.

West coast

- The US west coast has not as yet figured prominently as an exporter of seaborne LPG cargoes, with only Ferndale in Washington State shipping the occasional summer cargo of butane to Asia and Latin America. However, evolving conditions point to a change. Now that its traditional US overland pipeline market has evaporated, Canada is looking for new outlets for Alberta's plentiful NGL resources. Another consideration is the fact that the western shores of North America are only 12 days' sailing from Asia. Calgary-based Petrogas Energy purchased the Ferndale terminal from Chevron in 2014 and plans to increase its 900,000 tpa export capability. The target products are Alberta-sourced propane and butane; the target customers, buyers in Asia. Since the Petrogas acquisition two other firms have announced plans to build LPG export terminals on the US west coast.
- Sage Midstream is seeking to construct a 1.4 mt/year installation at Longview, Washington and a project unveiled by Pembina Pipeline calls for a 1.1 mt/year complex at Portland, Oregon. Ferndale is connected by rail to Alberta's LPG collection points, and Sage and Pembina plan to offer similar tank car deliveries by rail.

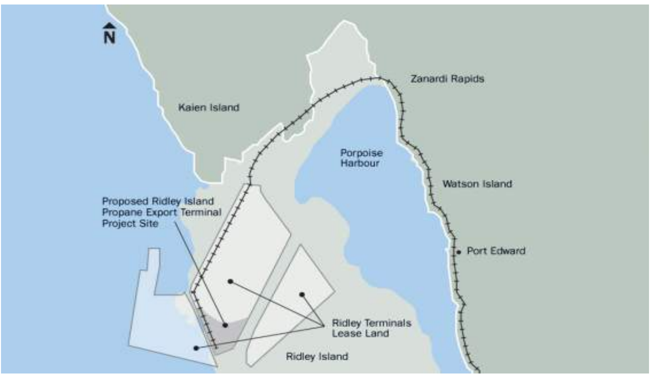
4.1.6. Canada

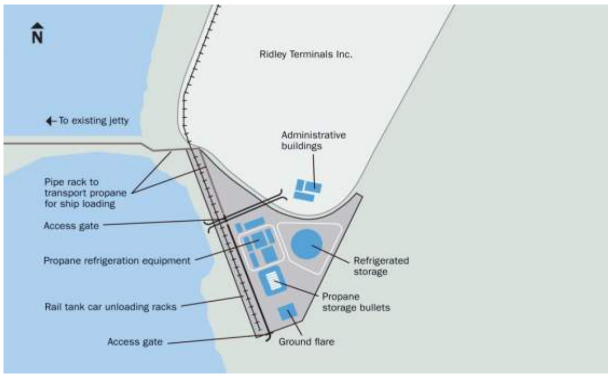
Western Canada produces about 150,000 bbl/day of LPG, which was traditionally sold to consumers in Ontario. LPG demand in Western Canada is estimated at only 25,000 bbl/day. he Middle East is currently the world's largest LPG exporter. The US Gulf Coast has been rapidly expanding LPG exports to Asia in the past 5fiveyears, with transit times closer to 25 days. LPGs are used as a petrochemical feedstock but are also increasingly being used to displace kerosene for heating and cooking.

Ridley Island Export Terminal

AltaGas announced a Final Investment Decision on the Ridley Island Propane Export Terminal. The Project is expected to be the first LPG export terminal on Canada's west coast. The Project is located on Ridley Island near Prince Rupert, British Columbia, on a section of land leased by Ridley Terminals Inc. from the Prince Rupert Port Authority. The brownfield site has a history of industrial development and benefits from excellent railway access and a world class marine jetty with deep water access to the Pacific Ocean.

It has been designed to ship up to 1.2 million tonnes of LPG per year. LPG from British Columbia and Alberta natural gas producers will be transported to the Facility using the existing CN rail network. It is estimated that the proposed Facility will offload approximately 50 to 60 rail cars per day and deliver by marine transport approximately 20 to 30 cargos of propane per year to market. The Facility is estimated to cost between $450 million and $500 million, and is expected to be in service by the first quarter of 2019.





The terminal is estimated to cost between $450 million and $500 million. The export terminal should hopefully alleviate some of the oversupply in Western Canada's propane market.

4.2. Market Drivers

The main drivers of LPG bunkering growth are the rising environmental concerns coupled with government initiatives towards adoption of LPG as ship fuel.

- Increased availability of LPG supply will drive to long term growth in demand for LPG as fuel.
- Major port trading hubs are well located to the existing LPG storage facilities that could supply LPG bunker for ships, if demanded by owners.
- Desire for charterer's and shippers to improve green credential.
- Gas fuelled fleet "projected" to grow to 250 by 2020, so there is an increased awareness for clean fuels.
- Desire for charterer's and shippers to improve green credential.
- Gas fuelled fleet (mainly LNG plus LPG) "projected" to grow to 250 by 2020, so there is an increased awareness for all clean fuels.

4.3. Barriers to Growth

There are several specific barriers, which may hinder the development of LPG bunkering infrastructure. Key issues are highlighted below. The Recommendations Chapter proposes suggestions to overcome these barriers.

With all the possible alternatives to polluting HFO, it is easy to wonder why none of the alternative fuels have been adopted by the shipping industry on a large scale. The explanation lies in several barriers and challenges that inhibit deviation from the status quo.

4.3.1. Difficult Regulatory Challenges must be addressed to enhance market opportunities- Lack of LPG Bunkering Operation Standards

Standards (at international level or regional/local level) for bunkering procedures, training, and equipment are necessary to ensure safe LPG bunkering operations for LPG-fuelled ships via bunker vessels, trucks, onshore installations, and portable tanks. These are not well developed today.

4.3.2. Upfront Investment Cost of LPG Infrastructure

Limited LPG bunkering infrastructure (along also other alternative fuels infrastructure) has been blamed for holding back the shipping industry's adoption of LPG as a fuel. It's a textbook chicken-and-egg problem: Fleet operators will not switch to LPG if they cannot be confident of supply, while suppliers will not invest if they do not see sufficient demand. Cost is the primary decision factor for the majority of ship owners, fleet operators, port authorities and LPG distribution companies in this sector. With strict budgetary pressures, many ship owners, charterers and fuel suppliers remain focused on immediate costs rather than long-term savings. Coordination and cooperation between port developers, ship owners, charterers and LPG distribution companies can be particularly difficult with ships in international trades.

4.3.3. Uncertainties in Future LPG Price Levels: The Main Drawback

LPG is lower priced than LSFO on a heating value equivalent basis. The main drawbacks of LPG are the price difference between LPG and HFO and mainly the uncertainties in future LPG price levels. Evidently, there is currently no LPG bunkering price and thus it is difficult to make accurate comparisons between competing fuels. This also explains why for the moment only LPG carriers have expressed an interest in using LPG propulsion.

4.3.4. Awareness/Perception: LPG Infrastructure, Barges and Ships need to be Considered by Stakeholders

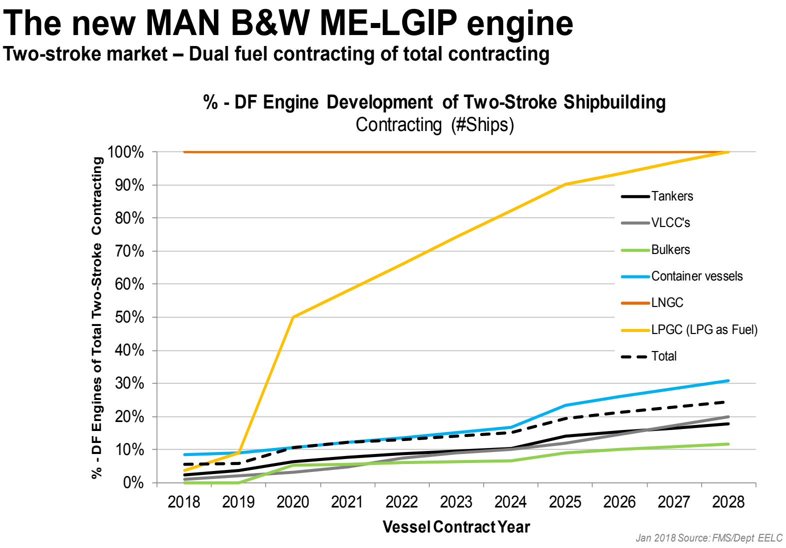
Raising awareness of the existence of LPG bunkering infrastructure is the first major challenge. There is information imbalance which results from the complex nature of comparing the wide variety of alternatives fuels over a large spectrum of interdependent factors, which requires a great deal of data, transparency along the entire value chain, and complex modelling. Public and political awareness about LPG benefits as fuel remains the strongest weakness in the marine market.

4.3.5. Complex Stakeholder Structure and the International Nature of Maritime Shipping

Many interdependent stakeholders – i.e. ship owners, ship operators, port authorities – each differently influence the choice of the fuel used on-board the ship fleet, driven by individual financial incentives and sustainability agendas. In the marine sector with low operating margins and high investments in ships with long life cycles (around 25 years), it is understandable that few players want to commit to an alternative solution under a high level of uncertainty.

4.5. LPG Potential Bunker Fuel Market Size

Today LPG is becoming a technically and economically feasible option as an alternative fuel for shipping. According to MAN, by 2028, all LPG VLGC's new builds and about 30% of containerships new builds are going to use LPG as fuel.



IHS Markit recently was mentioned 300 VLGCs as candidates.

Following the above estimations, LPG bunker fuel global consumption could be of the order of 100,000 tons around 2022 (through new builds in order), and is expected to increase rapidly the following years.

According to GECF[10] GGM, in 2040 global consumption of bunker fuels may reach 319 mtoe (millions of tonnes of oil equivalent) while global LPG bunker fuel consumption could be reaching 10 mtoe. Thus, in 2040 LPG bunker fuel share is expected to reach 3% of the bunker fuel market, while its share in the global LPG market is anticipated to be at around 2-2.5%.
LPG consumption per VLGC is estimated to 10000-14000 tons per year depending on many factors.

Table below gives estimated LPG consumption per ship type (seagoing)

LPG Consumption per Ship type	mt/hr	mt/yr
VLGC 84.000cbm, MAN 2-stroke Dual Fuel engine (24hr sail, 250 d/yr)	1.90	11400
Containerships (24hr sail, 250 d/yr)		
Mega Container ~ 20K TEU	2.50	15000
New Panamax ~ 14K TEU	1.70	10200
Feeder Max ~ 4K TEU	0.50	3000
Small Bulk Carrier and Tanker (24hr sail, 250 d/yr)	1.90	11400
Ferry with COGES (16hr sail, 250 d/yr)	2.00	8000
Ferry with Dual Fuel engine (16hr sail, 250 d/yr)	2.70	1080
High speed passenger catamaran ~ 350pax (16hr sail, 250 d/yr)	1.00	4000

10 The Gas Exporting Countries Forum (GECF) is an international governmental organization which provides the framework for exchanging experience and information among Member Countries

Chapter Five

Recommendations

The Roadmap section above identified the critical barriers to market uptake for marine engines with LPG. In this section, recommendations on how each of these barriers can be overcome are presented, especially as regards bunkering issues, and which type of market actors have a role to play.

5.1. Harmonisation of Regulations is an issue

- **Contacting** various legislators, regulators, societies such as International Association of Classification Societies (IACS), Society of International Gas Tanker and Terminal Operators (SIGTTO) and Society for Gas as Marine Fuel (SGMF) in order to promote the use of LPG as marine fuel and rules for LPG bunkering procedures. ROLE FOR ASSOCIATIONS.
- **Lobbying** to ensure worldwide standards and certification regulations for bunkering procedures. Associations, LPG companies and ports must ensure that policy-makers and regulators develop safe, reliable regulations. ROLE FOR ASSOCIATIONS.
- **Developing** safety measures to allow bunkering while passengers on board. ROLE OF ASSOCIATIONS.
- **Supporting** efforts to develop revised regulations. ROLE OF ASSOCIATIONS.

5.2. Customer Economics- Investment for Ship Owners and Fuel Suppliers is the Greatest Challenge

- **Providing subsidisation** could bring down the upfront cost, need to seek subsidy sources. ROLE OF INDUSTRY ASSOCIATIONS AND GOVERNMENTS.
- **Lobbying to ensure that LPG as engine fuel in marine industry receives a fair level of incentives t**o be on a level playing field with other competing technologies such as diesel, CNG, LNG. This will contribute to accepting an LPG engine as a preferable option. ROLE FOR INDUSTRY ASSOCIATION.
- **Price indexing and the wider use of long-term LPG contracts can be used to help mitigate the risk of wide LPG price fluctuations, and its associated unpredictability.** This would give existing and new customers greater confidence in future fuel prices of the fuel and therefore in the future commercial viability of their operations. The use of longer term contracts is more common in LNG markets than in LPG. LPG is more exposed to, for example, seasonal changes and short-term shifts in the supply-demand balance. In addition, while diesel prices are generally higher than those of LPG currently, the volatility can often mask this feature in the eyes of end users. ROLE OF LPG DISTRIBUTORS, SUPPLIERS.
- **Providing incentives** will bring down either upfront costs or running costs. ROLE OF GOVERNMENT.

5.3. Uncertainties in Future LPG Price Levels: A Concern for a Ship-Owner to Invest on LPG-Fuelled Ship

A major hurdle to the uptake of alternative fuels is the either comparatively higher cost of the fuels, or the high retrofitting cost for running on relatively cheaper gaseous fuels, which thus limits economic incentives of switching from cheap HFO. However, this cost barrier is expected to fade from 2020 onwards, with the advent of stricter global emission norms. Economies of scale should in the long-term result in a decreased cost of LPG and an increased access to capital for retrofitted ships that spend most their time in ECAs. Full price competitiveness of low carbon alternatives in the short- and medium-term can however only be achieved if GHG pollution in the shipping industry is being penalized by a set of carbon taxing measures. ROLE OF POLICY MAKERS & GOVENMEMENT.

5.4. Awareness for Decision Makers: Shared vision with marine, ship owners, ship operators and traders and fuel suppliers need to be considered

- **Stakeholders need to continue to collaborate** to support current and proposed marine LPG initiatives. There are major potential environmental and economic benefits to be realised if LPG is adopted as a marine fuel. ROLE OF ALL STAKEHOLDERS.
- **Marketing/awareness-raising activities** involving for example information dissemination demonstrating real technology performance, applicability and potential, targeted marketing events for ship-owners and operators,, information/training events, sector exhibitions, etc. ROLE FOR ALL MARKET ACTORS: ASSOCIATIONS, LPG DISTRIBUTORS.
- **Demonstrate** of LPG Bunkering infrastructure data. ROLE FOR ASSOCIATIONS and LPG DISTRIBUTORS.
- **Publishing** information documents and materials (brochures, charters of benefits etc.) with all types of related information, including safety, easily accessible to the stakeholders to increase understanding and address potential concerns related to LPG infrastructure.

5.5. Complex Stakeholder Structure and the International Nature of Maritime Shipping

- Ship builders and engine manufacturers influence the fuel choice by deciding on propulsion and abatement technologies on-board ships in the order fulfilment process.
- The shipping operators, who either own or lease ships, order the fuel which is compatible with the ship's propulsion technology and influence the fuel demand.
- Port authorities and terminal operators are responsible for providing necessary fuel bunkering infrastructure and fuel security at the ports.

Abbreviations

Bbl/d	Barrels per day
BTS	Barge to Ship
FSU	Floating Storage Units
FSV	Floating Storage Vessels
EIA	Energy Information Administration
GHG	Greenhouse gases
HC	Hydrocarbons
IGC	International Gas Code （Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk)
IGF	Code of Safety for Gas-Fuelled Ships
IMO	International maritime organization
LEZ	Low emission zones
LFL	Lower Flammability Limit
LSHFO	Low Sulphur Heavy Fuel Oil
MARPOL	International Convention for the Prevention of Pollution from Ships
MMBtu	Mcf Millions of BTUs
Mtoe	Million Tonnes of Oil Equivalent
NMHC	Non-methane hydrocarbons
MoS	Motorways of the Sea
mt	Metric tonnes
NOx NO and NO_2	Nitric oxide and nitrogen dioxide
OEM	Original equipment manufacturer
PM	Particle mass
PN	Particle number
PPM	Parts per million
PTS	Port to Ship
THC	Total hydrocarbons
VOC	Volatile organic compounds
VRLs	Vapour return lines
STS	Ship to Ship
SPM	Single Point Mooring

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