2012 – 2015 Triennium Work Report

June 2015

Small Scale LNG

Program Committee D3

Produced by:
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1 Executive Summary

Fifty years ago, the first commercial LNG cargo was shipped from an LNG export facility in Algeria in 1964. Since then, LNG has grown into a truly global commodity. This growth has been accompanied with, and driven by, economies of scale in the design and construction of facilities. Since the first trains in Algeria of 0.4 mtpa LNG, the conventional LNG business has evolved into 7.8 mtpa mega-trains in the 77 mtpa Ras Laffan Industrial City in Qatar

In recent years, a comeback of smaller scale LNG facilities has emerged. New liquefaction and distribution facilities are being constructed and operated across the globe. Currently, the global small-scale LNG (SSLNG) installed production capacity is of 20 mtpa spread around more than hundred SSLNG facilities. This is on top of the installed capacity for conventional LNG plants of approximately 300 mtpa. The SSLNG market is developing rapidly, especially as a transportation fuel and to serve end users in remote areas or not connected to the main pipeline infrastructure.

This report, written by the IGU Program Committee (PGC) D3, provides an overview of this new and dynamic SSLNG business worldwide. Its objective is to increase awareness and understanding in this area as a basis for an informed discussion on how to further develop this industry. In terms of scope, this study considers the wholesale SSLNG supply chain, including production, liquefaction, transport, reception, break-bulk and regasification. The IGU defines small scale liquefaction and regasification facilities as plants with a capacity of less than 1 mtpa. In turn, SSLNG carriers are defined as vessels with a LNG storage capacity of less than 30,000 cubic metres. The retail LNG business is described in the Program Committee (PGC) D2 report on LNG as fuel, which covers the more user-oriented supply chain, including distribution and end-use.

The global commoditisation of LNG has provided a solid base for the emergence of new LNG applications and markets. The key drivers for SSLNG are environmental, economic and geopolitical. The environmental benefits of LNG in terms of CO_2, SO_x, NO_x and particulate emissions are undisputed when compared to alternative fossil fuels but it also needs to have a transparent and profitable business model to be feasible. The supply chain can be rather expensive due to the diseconomy of the small scale and the relatively small size of the market, but as technology solutions mature, standardisation, modularisation and therefore competitiveness are expected to increase. The lower entrance hurdle compared to large LNG projects opens up opportunities for creativity and fast new technology deployment.

Most of the growth is in China where efforts are in place to get clean fuels to fight air pollution in the cities, stimulated by the availability of gas and the price differential between natural gas and diesel. Price arbitrage is also the primary driver in the US with the abundance of shale gas. Stricter regulations on the marine sector are stimulating the use of SSLNG as bunker fuel in Europe (Scandinavia, Baltic and NW Europe). In Latin America, the key drivers are the monetisation of stranded gas supplies and the need to reach remote-located consumers. Significant SSLNG import, break bulk and regasification is already present in China, Japan, Spain, Portugal, Turkey and Norway with hundreds of small terminals and it continues to grow to service remote local areas and fluctuating consumption profiles.

The development and maturation of SSLNG technology are key enablers for the pursuit of the SSLNG business. Here, significant progress has been made in all areas across the value chain. In the liquefaction plants, the development and optimisation of a wider range of processes and equipment helped to counter the diseconomy of small scale and to reduce initial investment cost. The application of pressurised LNG tanks provides a more cost-effective means for storing smaller parcels of LNG when compared to the conventional atmospheric flat bottom tanks. It also allows for a more effective way to manage boil-off gas (BOG) and pressure build-up across the value chain, thus eliminating the need for more expensive BOG compression solutions. Developments in shipping (cargo containment systems, commoditisation) and transfer (ship-to-ship transfer, emergency shutdown and release systems) also support the trend towards more fit for purpose solutions in SSLNG. New project execution principles such as modularisation, containerisation, replication and standardisation enable further growth of LNG. Small scale LNG creates opportunities for lean operational and maintenance strategies, i.e. unmanned operation, multi-disciplinary staff, etc.

However there are still many challenges. One of the challenges of SSLNG globally is meeting the security of supply and demand, for example to overcome the concern of customers to step into the SSLNG market with only limited supply alternatives available. Some SSLNG opportunities become only feasible with a complete supply chain development, from well to end-customer. The challenge here is to operate and design all elements within such a supply chain effectively and competitively. The development of cost-effective, modularised and standardised supply networks is crucial to overcome this challenge. Another challenge is the implementation of a fiscal regime and a regulatory framework, conducive to investment decisions for SSLNG opportunities.

An important consideration is the impact of the recent drop in oil prices in the investment decision for natural gas and LNG projects. This is expected to affect the SSLNG business in particular, due to its fast-responding nature and because these projects require large oil/gas price differentials, that may no longer be available in the current oil price scenario.

The development of downstream infrastructure and logistics – remote regas facilities, bunkering and trucking stations - is key for building up a robust market for SSLNG.

Historically, LNG has displayed a very good safety track record. The very high reliability and safety level achieved by the traditional LNG industry does not guarantee that the same safety standards can be maintained for the small scale business due to the many differences between the two business models. For example, due to the large number of smaller parcels and multiple players in a rapidly growing market, the SSLNG business is scattered and more challenging to manage. Sharing of best practice, developing consistent national and international safety standards and creating a certified training level for staff involved in SSLNG are needed to maintain the high safety standards of the industry.

The expectation for the small scale LNG business is that the expansion will continue towards 2020, growing towards a 30 mtpa business globally. This growth is predicated on the implementation of a level playing field, with economic incentives and robust environmental regulations, on technology developments driving down costs, and on the sustainability of a competitive price spread between natural gas and oil.

2 Introduction

In the early days of the LNG industry, facilities were displaying capacities that would be regarded as small scale LNG (SSLNG) today. As an example, the first terminal in Canvey island in the UK was equipped with six tanks of 4.000 ton installed capacity each in 1964. The first conventional LNG plant started up in Arzew, Algeria consisting of three liquefaction trains with a total capacity of 1 mtpa. Gradually the size of the LNG facilities increased significantly bringing economies of scale. Meanwhile it seems that the economy of scale has reached its upper limit with the 7.8 mtpa mega trains in Qatar.

Due to several factors, SSLNG has regained attractiveness over the last couple of years. New environmental emissions policies and arbitrage in oil and gas prices have led many regions to begin building up small-scale infrastructures. In addition, the wider availability of LNG due to new projects and modifications of existing import terminals to enable redistribution of LNG also contributed to this development. SSLNG is up to now mainly taking place in the US, Europe and China.

The challenge related to the SSLNG business is a relatively expensive supply chain due to the absence of economies of scale. Nevertheless it is increasingly becoming the preferred delivery method for natural gas because LNG can be produced at remote locations and distributed to (remote) end-users conveniently.

Due to the emerging nature of this SSLNG market, statistical figures are not yet available. Figures and volumes on SSLNG provided in this report are the result of thorough research of the study group, but may not be exhaustive. With a total amount of approximately 100 small scale LNG production plants globally, the total SSLNG installed production capacity is towards 20 mtpa of LNG, approximately 5% of the global conventional LNG production (LNG, 2014 Edition). The majority of the SSLNG production is in China, where approximately 100 - 150 plants cover 15mtpa installed capacity and total planned capacity is expected to reach 21mtpa by 2020. For transport overseas, there are currently 24 LNG carriers in operation with less than 30.000m^3 cargo capacity and the order book is filled with 14 new small scale LNG carriers. The number of (very) small scale regas- and import terminals is in the thousands, mainly located in Japan, Turkey, Spain and Northern Europe. Whereas the sector of small scale LNG wholesale and retail has been so far populated by small players, the recent growth is determined by the ingress of some of the big LNG players (Shell, Gazprom, Petrochina). See Figure 1 (LNG, 2014 Edition) for the global SSLNG existing markets and developments.

Figure 1 Small-Scale Liquefaction and Regasification Capacity, 2014. Source: IHS (edited version)

An introduction to the small scale LNG value chain was covered in the 2014 World LNG report. In the 2012-2015 IGU triennium the small scale business is captured in all its complexity.

To this aim, two dedicated groups worked through the triennium:

1. PGC-D3 focussing on Small Scale LNG "Wholesale" - This Report
2. PCG-D2 focussing on LNG Retail - See "LNG as Fuel"

The reports are clearly linked with each other because a significant part of the SSLNG wholesale originates from the demand for LNG as fuel. However, a visual differentiation is shown in Figure 2.

As SSLNG is a dynamic, fast-moving industry, the information presented here is a representative sample of the current industry; all developments may not be included.

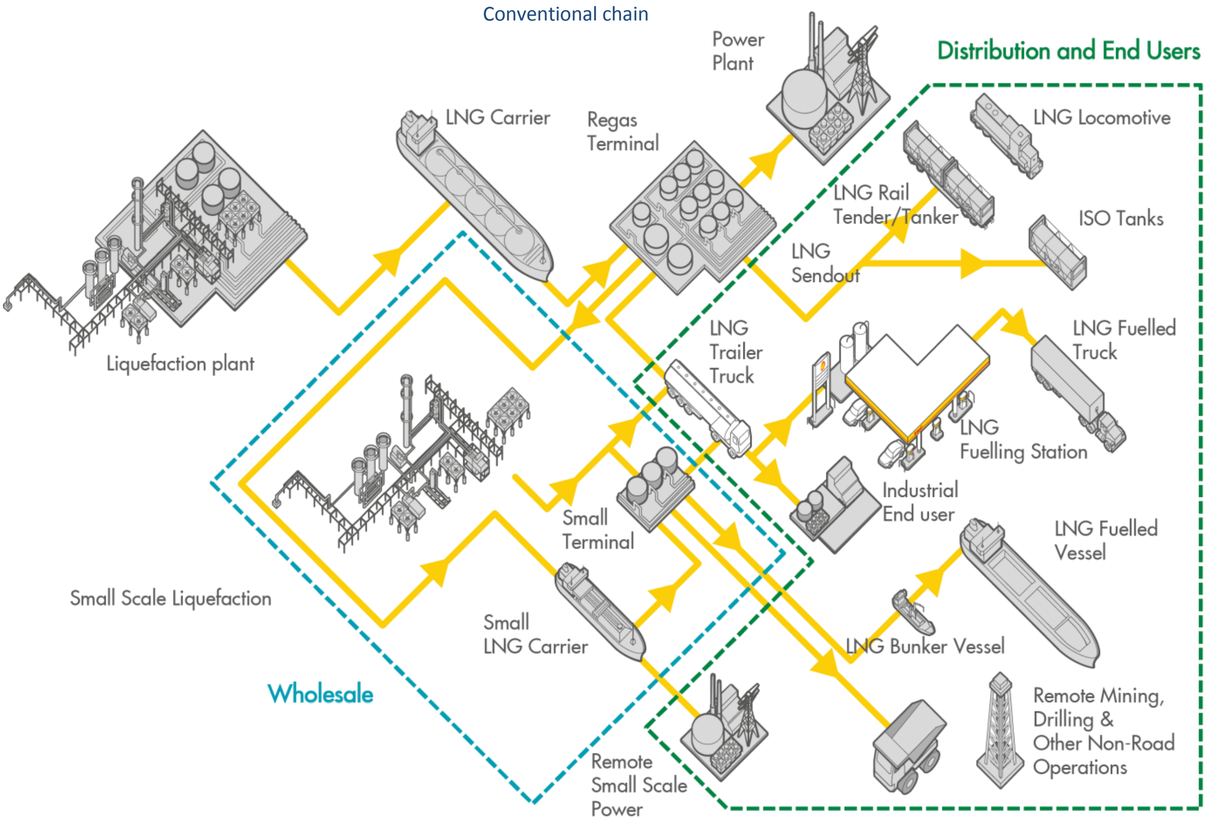


Figure 2 Small Scale LNG Value Network, Wholesale and Retail. Source: Shell (edited version).

To cover the wholesale SSLNG market from all perspectives, the main aspects are included in this report. In the next chapter, the definition of small scale LNG is given, followed by drivers and business models. Because China contains the most small scale LNG business, a special "China case" chapter is added to this report. In the parties chapter, an overview of the type of companies involved in SSLNG and their interaction is given. In the technology overview, the technology aspects of the main modules of the SSLNG supply chain (liquefaction, transport, storage etc.) are shared. After that, the safety aspects of SSLNG are described and the SSLNG specific standards and regulations. The report ends with a conclusion that contains a status update of the SSLNG industry and recommendations.

3 Definition

3.1 Value Network Small Scale LNG Wholesale

While in the conventional base-load LNG business it is possible to talk about a “value chain”, mainly consisting of a liquefaction plant, transport, regasification and end-users (power plant or domestic), the small-scale business is better described as a “value network”. As shown in Figure 3, SSLNG can be sourced from an existing conventional scale LNG facility, such as the liquefaction or regasification facility, or by a small scale liquefaction facility itself. It typically serves a wider range of end users than the conventional value chain.

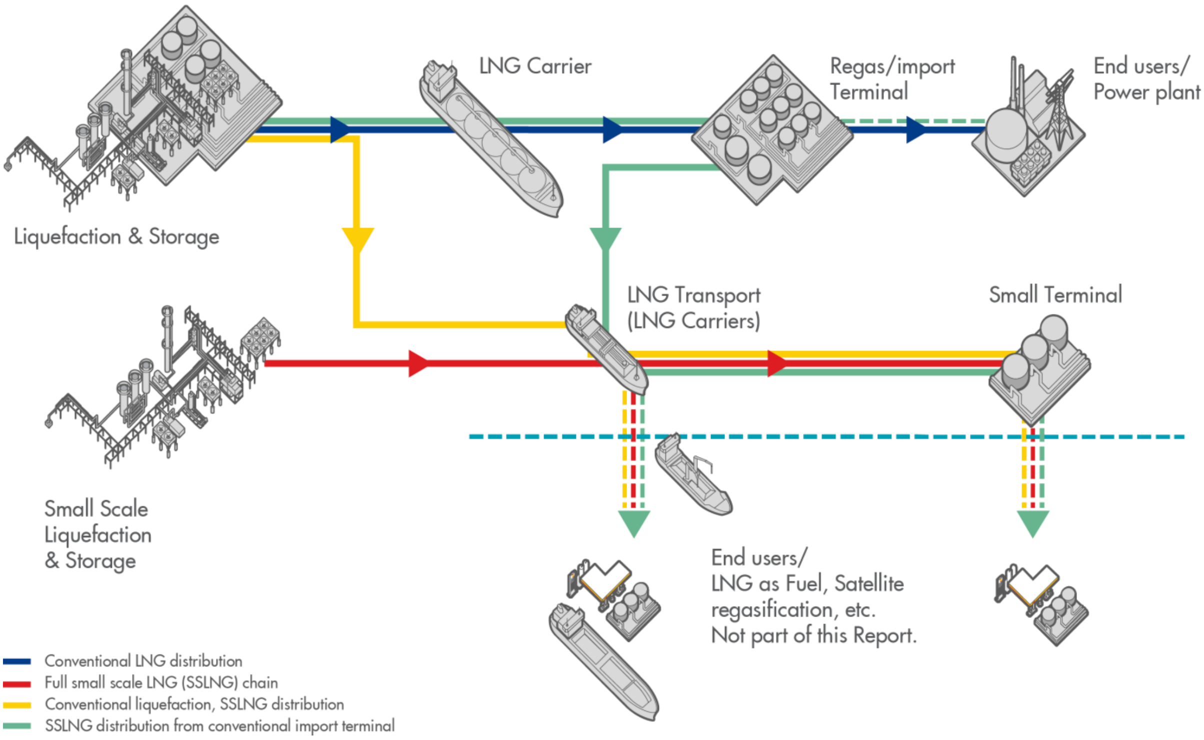


Figure 3 “Five different logistic LNG distribution methods in Small Scale LNG Wholesale”. Source: Shell (edited version).

As an example of the value network options, several coloured lines are shown in the diagram above. The blue line shows conventional LNG distribution. The others represent small scale variants: the red line represents a full SSLNG chain solely; the red line represents SSLNG at liquefaction. The yellow line represents SSLNG from conventional liquefaction, being break-bulked and shipped in small parcels to the small scale terminal. The green dotted line represents small parcels from the regasification and import terminals to a local or remote power plant, not connected to the gas grid. If the demand of LNG is solely coming from small LNG terminals, there is no regasification, and the facility receiving the LNG is called an import terminal (i.e. solid green line). The end-customers can also be served from the larger storage facilities or the small terminals. This is not part of this report; please see the report “LNG as Fuel.

3.2 Scope

Producing LNG at a small scale so that it can be used for transport purposes and small industrial applications requires a different mind-set compared to the conventional large scale LNG chain. Supported by improvements in technology and economics, the SSLNG business has rapidly expanded from simply a small replica of larger scale business to customized SSLNG solutions.

For the purpose of this report, the SSLNG production installed capacity has been defined as below 1 million tons per annum (mtpa). For practical reasons, a lower limit of 0.05 mtpa installed capacity also has been adopted. The upper boundary has been set with the objective of capturing all the LNG projects that do not belong to the conventional LNG projects. The lower boundary has been set to avoid describing a multitude of very small projects which are flourishing in some regions of the world, for example small peak-shaving projects in China or the US, which were considered to be best captured at high level.

For regasification and import terminals, the throughput is defined as 0.05 mtpa to 1.0 mtpa.

For the transportation of LNG in wholesale, this report captures small LNG carriers up to 30.000m^3, which is typically the maximum small scale currently observed in industry. The shipping fleet and characteristics are further discussed in chapter 0.

For tank farms, the storage capacity is used in the wholesale framework, with the minimum set to 500m^3 storage capacities in order to exclude the micro projects. As with LNG carriers, also tank farms can be divided in two categories: conventional concept atmospheric operated storage and pressurized storage. Typically, in small scale LNG a greater number of different technologies are being deployed.

To ensure that the list of projects taken into account is robust, only projects which have passed final investment decision (FID) have been considered. This was necessary because of the large number of projects mentioned in the open literature. Although it was not taken into account and not all have a solid basis, the number of projects under development can be seen as a testimony to the big excitement about the possibilities that the SSLNG sector offers.

The scope of this report is summarized by Table 1.

Item	Min	Max	Dimension
Value Network	LNG Wholesale (for Retail, see LNG as Fuel)		
Projects and Assets	Post-FID and in Operation		
LNG Transport method	SSLNG Carrier (for other transport methods see “LNG as Fuel” report)		
LNG Production Units	0,05	1	(Installed) million tons per annum
Tank Farm (import/export)	500	30.000	LNG storage capacity m^3
Regas Terminals	0,05	1	million tons per annum
LNG Carriers	0	30.000	LNG storage capacity m^3

Table 1 LNG Small Scale Wholesale covered by this report.

4 Drivers and Business Models

4.1 Drivers, Enablers and Challenges

4.1.1 Key Drivers

The key observed drivers for SSLNG developments are:

- Economics: energy cost advantage of LNG over alternative energy sources for end-users, including gas in the absence of pipeline infrastructure. An example is given in Figure 4 for the use of LNG as transport fuel compared to diesel.
- Environmental: small scale LNG can bring attractive environmental benefits both to the gas production (preventing flaring) as well as end-customer use (LNG for transport / power & heating generation), compared to alternative fossil fuels. This includes CO_2, SO_x, NO_x, particles and noise emissions.
- Governmental decisions to increase the level of energy independence for a country or region by developing an alternative energy supply.

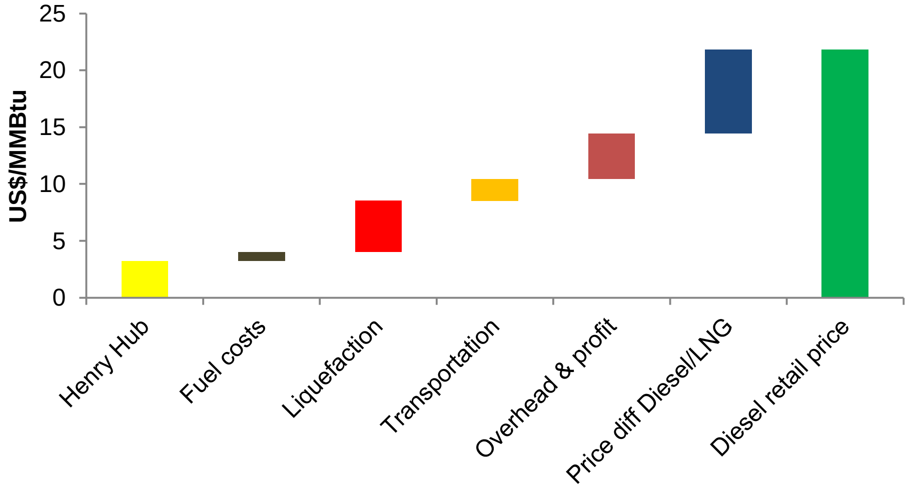


Figure 4 Example of SSLNG value chain cost. Partly sourced from: PlumEnergy May 2013- www.glmri.org public domain.

Most business opportunities have multiple drivers. SSLNG production has been traditionally considered an important business in North America, Asia (China, Japan) and Europe (specifically in the Scandinavian region). The relevance of the drivers for small scale LNG varies per region, see Figure 5. For example in Scandinavia, the main driver is environmental, where the main drivers in the US are mostly economic and China mostly both economic and environmental. Geo-political drivers for national governments are entering the SSLNG space recently as well, mainly for customers to become more independent of pipeline gas suppliers.

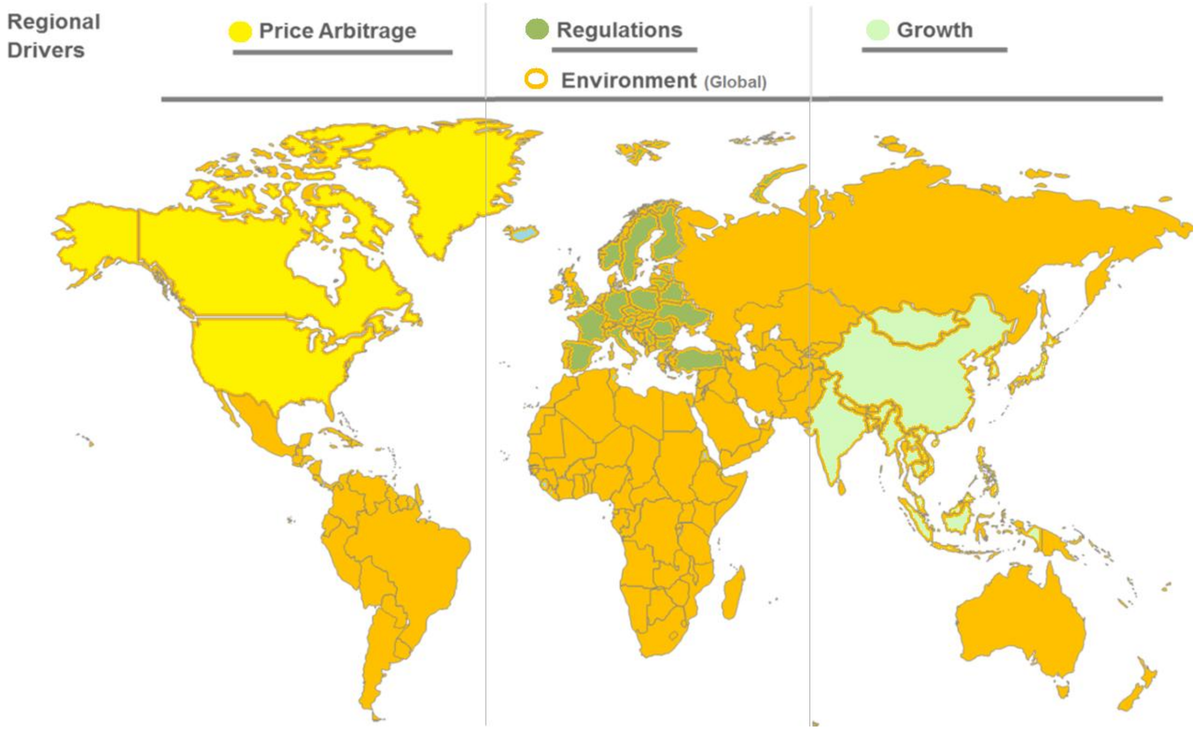


Figure 5 Regional Main drivers for SSLNG. Environmental is global. Source: Shell (edited version).

4.1.2 Key Enablers

Below the key enablers:

- Technology: the development and maturation of small scale LNG technology is seen as the key enabler. For example, more efficient and cost-effective small scale liquefaction processes are being developed, while for LNG as transport fuel, gas engine technology is rapidly developing.
- Financing: the availability of relatively “cheap” money can generate regional attractiveness to invest in SSLNG projects and attract new players to the market. The SSLNG projects require lower investments as they are smaller than conventional projects. Even with these lower investments, most companies need a certain level of commitments from its customers.
- Fiscal regime and subsidies: in some cases, small LNG production projects can help to develop natural gas consumption both as a temporarily supply or to feed remote areas that are not connected to the main transportation grids. Therefore the (local) authorities can provide attractive fiscal packages that support LNG development. Various European countries have proposed building small-scale import terminals, supported by EU subsidies that could be as large as 10-20% of the terminal development cost. Alternatively, more polluting fuels may be subject to higher taxation.
- Stimulating policy and regulations: enforcement of environmental benefits is typically imposed by government interventions through policies or regulations (ECA zones).

4.1.3 Key Challenges

Below the key challenges are given.

- Cost: the main challenge of the SSLNG industry relates to the costs due to the lack of economies of scale and expensive materials (cryogenic).
- Fit-for-purpose engineering: SSLNG has attracted big and smaller players to the market. For the larger players, an observed challenge is to develop cost-effectively and fit-for-purpose technological solutions, while not compromising company and safety standards.
- Safety: for new players entering the SSLNG market, maintaining safe and reliable operation can be a challenge when lacking LNG experience. Additionally, the SSLNG network involves many parties and smaller parcel sizes, requiring a framework of standards and guidelines to maintain the current safety level in the industry.
- Availability of supply and demand: the growth of the SSLNG business is linked to deliverability and sustainable demand for LNG. This creates a potential stalemate where consumers wish for security of supply before committing to LNG, while potential suppliers need to secure a market to justify the investment. The unlocking of such a dilemma is being addressed in different ways in different parts of the world. This challenge will disappear gradually as the market develops further and SSLNG becomes a more widely traded commodity.
- Full supply chain development: several SSLNG opportunities become only feasible with a complete supply chain development, from source (gas field, pipe-line), all the way to end-customers. Many parties have looked at elements but there are very few examples of parties that have succeeded on creating a full small scale supply chain. The challenge here is to operate and design all elements of such a supply chain effectively and competitively.
- Lack of (consistent) and change of policy and regulations: mainly for less developed markets the absence of policies should be considered when developing a new SSLNG project in a country without previous experience in LNG, in such a case, the developers should refer to and use the available international set of standards and guidelines

Time and experience is expected to offset these challenges as this SSLNG industry becomes more mature.

4.2 Business Models and Scenarios

4.2.1 Business Models

In the SSLNG value network, money can be earned by owning the assets, by trading the commodity or by both.

An asset owner may utilize the assets for its own purpose in case he owns the commodity. If there are multiple partners owning a facility, a joint use agreement over the facility is required. Examples are integrated players such as GDF Suez, Petrochina, Shell, Total. These asset owning parties may also apply a so called merchant model. The feed gas is in this case bought from another party. An example of a company applying such a merchant model is Gasnor in Norway. Gasnor buys the feed gas for its liquefaction plant from the market (different suppliers).

Alternatively, the asset owner can offer the use of the assets to third parties as a service provider, in which case the asset owner does not own the commodity. A good example is a ship owner that owns and operates the ships on behalf of a charterer (example: Anthony Veder, Skaugen/Norgas, Golar). Another example is in the LNG production part of the value network, where the owner of a liquefaction plant has a tolling agreement in place with one or more customers who own the molecules.

The business models used in SSLNG are derived from the conventional LNG business and may apply to the business scenarios as described in the following section

4.2.2 Business Scenarios

4.2.2.1 SSLNG Production

Monetization of gas liquefaction (LNG as commodity) can be currently realized by;

- Peak shaving
- Remote and stranded supply
- LNG as transport fuel
- Remote demand

These are described in more detail in the paragraphs below.

In addition, the following integrated business models are possible;

- Fully integrated model where the company which develops the gas supply also holds all the required facilities for production and commercializes to the final destinations. If there are multiple partners, a joint use agreement over the facility is required.
- Merchant model: as above, but here feed gas is bought from another party.

4.2.2.1.1 Peak shavers that benefit from fluctuating demand

Originally, SSLNG production units were often used as peak shavers to help meet seasonal and peak hour demand. These facilities contain both liquefaction and re-gasification capabilities to more compactly store gas until times of peak demand, when the LNG can be quickly re-gasified for use in retail applications, such as power generation or residential consumption. In the US, these projects put in place small scale liquefaction facilities to take gas from a conventional source (typically a gas pipeline) and store it in small scale storage so as to be able to regasify the stored volumes for peak demand seasons. These kind of projects have mainly a commercial driver (storing gas when gas prices are lower for regasifying when gas prices are higher). An overview of the peak shavers in the US is given in Appendix J.

4.2.2.1.2 Remote and stranded Supply

In the case of stranded gas supply, several solutions are available for gas resources monetization. Stranded gas can either be triggered by a gas flaring reduction objective or from a remote gas resource without any infrastructure available around to handle gas.

Special purpose projects for small size gas resources that would be stranded by conventional gas pipeline/LNG means. A small scale liquefaction project is the most feasible monetization route for the gas resources. Typically, LNG competes with other means of gas monetization, i.e.:

- Pipeline
- CNG
- Gas re-injection
- Gas to power
- Gas to methanol
- GTL
- Other

The decision on the best transport and monetization method for gas mainly depends on the distance between supply and customer, market size, gas price and volume.

4.2.2.2 LNG as Transportation Fuel

LNG is considered a more environment friendly alternative to traditional fuels as natural gas is the cleanest burning fossil fuel. LNG can be used as a fuel in the transport sector, for heavy duty trucks and for the marine sector. The LNG can be sold with a premium when competing with gasoline, diesel, marine gas oil (MGO) and even compressed natural gas (CNG). The construction of liquefaction units for the purpose of providing LNG as a fuel for transportation is a more recent phenomenon that has gained fast ground in China and US and is growing around the globe. In both countries, LNG is widely used in the trucking industry; China in particular has rapidly built up its domestic liquefaction infrastructure to replace diesel and cut vehicle emissions. Another example is LNG in marine transportation, which is the biggest demand and driver for potential SSLNG facilities within the Scandinavian and Baltic region. In order to operate, vessel owners and charterers will have to comply with the regulation of the Sulphur Emission Control Area (SECA's). An overview of the marine emission control areas (ECA) is given in Figure 6, (Global, Feb 2013).

Figure 6 Existing and possible future Emission Control Areas. Source: DNV-Greener Shipping in North America.

4.2.2.3 SSLNG Receiving Plants for Remote Demand

In certain regions, it is economically more attractive to develop a local SSLNG facility and associated distribution chain to supply remote locations in the area than other alternatives such as pipeline grid, supply from large scale LNG, etc. These are usually called “satellite plants”.

These satellite plant projects typically make use of trucks, LNG iso-containers, LNG railcars or small LNG carriers to reach remote and small gas consumers (that have small scale regas capacity). The source of supply can be both LNG from a conventional receiving facility, small scale receiving plant or small scale liquefaction from a source of gas (i.e. gas pipeline).

4.2.3 Small Scale LNG Transportation

4.2.3.1 Small Scale LNG Carriers

In a wholesale framework, only small LNG carriers are considered for transportation (refer to section 3). Nevertheless, in the start-up phase, smaller transportation unit such as trucks, containers or railcars may be an option in the absence of sufficient volume.

As for conventional LNG projects, the LNG sales can be done on free on board basis (FOB, sales at the exit flange of the LNG producing facilities; transportation to be arranged by the buyer), cost, insurance and freight (CIF, sales and insurance till directly after the flange of customers receiving facilities, transfer included) or delivered ex ship (DES, sales and assurance before the inlet flange of customers receiving facilities, transfer excluded). Typically, in a growing market like SSLNG, DES is used because there are limited delivery options. When the market becomes more “liquid”, FOB may become more attractive.

It is observed that for economical and logistical reasons, a significant part of the small scale LNG fleet is in operation for a combination of products (LNG/Ethylene/LPG), see Appendix G. Also, customers can charter the vessels based on a full time charter (100%), but also on the basis of “contract of affreightments” (COA). In this situation the customer may for example use the vessel for only one or two weeks per month. Ship brokers try to match shipping capacity demand and supply.

Figure 7 Pioneer Knutsen (1.100 LNG m3). Source: Gasnor AS (Shell)

4.2.3.2 Break-bulk projects

Break bulk facilities receive conventional LNG carriers and the LNG cargoes will be split into smaller volumes. These smaller volumes are transported from such facility by SSLNG Carriers to SSLNG import terminals. Very often it implies a SPA between a molecule owner (which is a capacity holder in the break bulk terminal) and the SSLNG off taker. An example of such a project is the GATE break-bulk facility in Rotterdam area. More terminals are developing a break-bulk solution for small scale LNG. The break bulk infrastructure has to be capable of receiving conventional LNGCs as well as SSLNG carriers. An overview of terminals in Europa that are being modified to allow truck loading or ship reloading is given in Appendix H.

The modification from a conventional import or export terminal to a terminal that can facilitate breakbulk and small scale LNG transfers, introduces challenges. Typical challenges are battery limit compatibility of existing infrastructure with new SSLNG equipment (LNG trucks, small LNG carriers, manifold forces). Another challenge might be LNG quality, especially when a certain methane number is needed for LNG as fuel. Typically, also the increase of amount of stakeholders makes the operation and ownership aspects more complex. Logistical challenges arise with the increasing amount of smaller parcel sizes.

Offshore break-bulk is also a possible concept, by ship to ship transfer, typically from a large to a small carrier.

4.2.3.3 Milk-run

In a milk run pattern, the vessel unloads partial cargoes to more than one destination. Indonesia is an example where small scale LNG is distributed via this concept. The advantages of a milk-run scheme are:

1. Making use of existing LNG fleet (incl. availability in case of LNG carrier failure)
2. Sharing shipping costs between more locations
3. Taking advantage of economies of scale related to conventional LNG carriers (big volume)

The challenges are:

1. Marine access for big ships potentially triggering significant investment (dredging, port service such as tugs, big berth for small facilities)
2. Arbitrage of distributing the shipping cost among the customers
3. Distance between customers can only be limited, in order to make it economically viable.

Some technologies that can cope with sloshing issues might be preferred in case of partial cargo tank offloading.

4.2.4 Small Scale LNG Consumption

The target consumption market is the starting point for setting up every business model. In the subchapters below, the main scenarios where LNG consumption comes into play are given.

4.2.4.1 LNG as Transportation Fuel

This market segment is described in the report ”LNG as Fuel”.

4.2.4.2 Remote Demand

The biggest market for small scale LNG is remote demand, where the consumers are not connected to the main gas pipeline grid.

- Power generation (typically few hundreds MW)
- Industrial use (off grid plant, plants like aluminium factories, steel etc)
- House-hold gas grids (satellite low pressure grids) / district heating

The majority of small independent re-gasification terminals are used to import globally-produced LNG, and are located in areas with limited demand or size constraints. For example, Japan holds most existing small-scale import terminals, many of which were built as satellite plants near larger, older terminals, though some can attribute their small size to space constraints or lower demand.

Another example is Nynäshamn in Sweden, where LNG is imported from a small production facility in Stavanger, Norway. Nynäshamn supplies gas to a refinery and provides LNG by truck to a limited number of customers in the vicinity of the plant.

4.3 China Case

China currently has the largest SSLNG market globally. The growth of SSLNG has been enormous during the last decade due to the availability of domestic gas, low state-controlled gas prices and the steer from the central and local governments to get cleaner fuels to help fight air pollution in the cities. The majority of the plants are in the northern and western provinces, mainly along the natural gas pipelines and often close to the LNG for road transportation markets. The price difference between natural gas and diesel is the primary driver for a shift to LNG as truck fuel in China, usually allowing cost recovery for the conversion within roughly a year. The LNG fuelled road transport market started booming with techno-commercial development in 2009. Currently the number of (heavy) trucks using LNG as fuel is approaching 200,000. Recently the first LNG marine bunker fuel station was opened and the Chinese government is trying to copy the success of LNG as road transport fuel to the (inland) marine market.

Gas supply is predominantly from pipelines delivering domestically produced gas or imported gas from Central Asia. However gas sources are currently moving towards cheaper sources i.e. cold bed methane (CBM), wellhead, and coke oven gas (COG) upon the NG price reforming.

Due to the sheer size and dynamic of the SSLNG market in China it is challenging to provide exact figures for SSLNG liquefaction plants already installed or in construction phase. A research from Wood Mackenzie revealed approx. 100 plants while a market investigation performed by Linde identified close to 150 plants by the end of 2014. Total installed liquefaction capacity is in the range of 15-20 mtpa. Below in Figure 8 is an illustration of the growth and owners of the production plants prepared by Shell.

The SSLNG business in China in particular benefitted from comparably low domestic natural gas prices, which are regulated by the state-run National Development and Reform Commission (NDRC). However with a growing LNG import business to China from international markets, national Chinese oil companies acting as LNG importers did not earn money. This led the NDRC to raise domestic natural gas prices significantly in 2013 and 2014. At the same time the NDRC controlled ceiling price for domestic LNG has been lowered to keep the incentive for LNG as fuel in comparison to gasoline, which dropped as a consequence of the crude oil price fall. While these new boundary conditions kept LNG attractive for end users of this fuel, e.g. truck fleet operators, the business for liquefying domestic pipeline gas almost completely lost its economic viability. Over and above this currently unfavourable business environment for SSLNG liquefaction plants, the utilisation rate of the existing plants is quite low, leaving room for a growing market without the immediate need of adding new liquefaction capacity. These latest developments resulted in 2014 in a remarkable decrease of new SSLNG liquefaction projects sanctioned. While there had been a steady rise of the yearly number of projects with FID since 2005, this number dropped to only on third of the 2013 figure in 2014.

The knowledge and experience in LNG technology in China follows the growth of this industry. Chinese companies increase their cost-competitiveness, although the difference in design standards used can make it difficult to compare. Over and above especially the state owned companies are driven by the Chinese government to develop their own liquefaction processes and key equipment. A clear observation is that local companies are continuously increasing their market share. For the liquefaction capacities above 800 tpd international technology providers had been the only choice a few years ago. Meanwhile companies like CPE-Southwest, HQCEC, Chengdu Cryogenic, Sichuan Air Separation, Lvneng and Harbin Cryogenic have gained in the order of 50% of the market share in this business segment. In the market segment with liquefaction capacities below 800 tpd almost all plants are nowadays awarded to local Chinese companies.

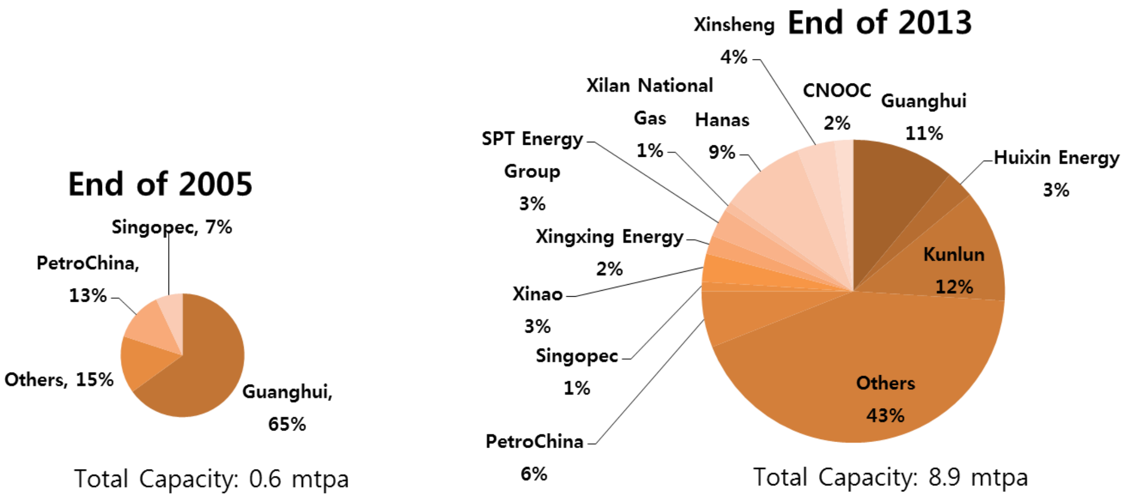


Figure 8 Chinese liquefaction plant owners in 2014. Source: Shell (edited version).

5 Parties involved in the Small Scale LNG market

5.1 Overview of the Value Chain

This section describes the parties involved in the small scale LNG chain as well as their role and interactions in this value chain. Figure 9 depicts different configurations and options of LNG flows through the value chain depending on the business model chosen and the options in the region. In appendix E, a comprehensive overview of some of the companies involved in SSLNG is given.

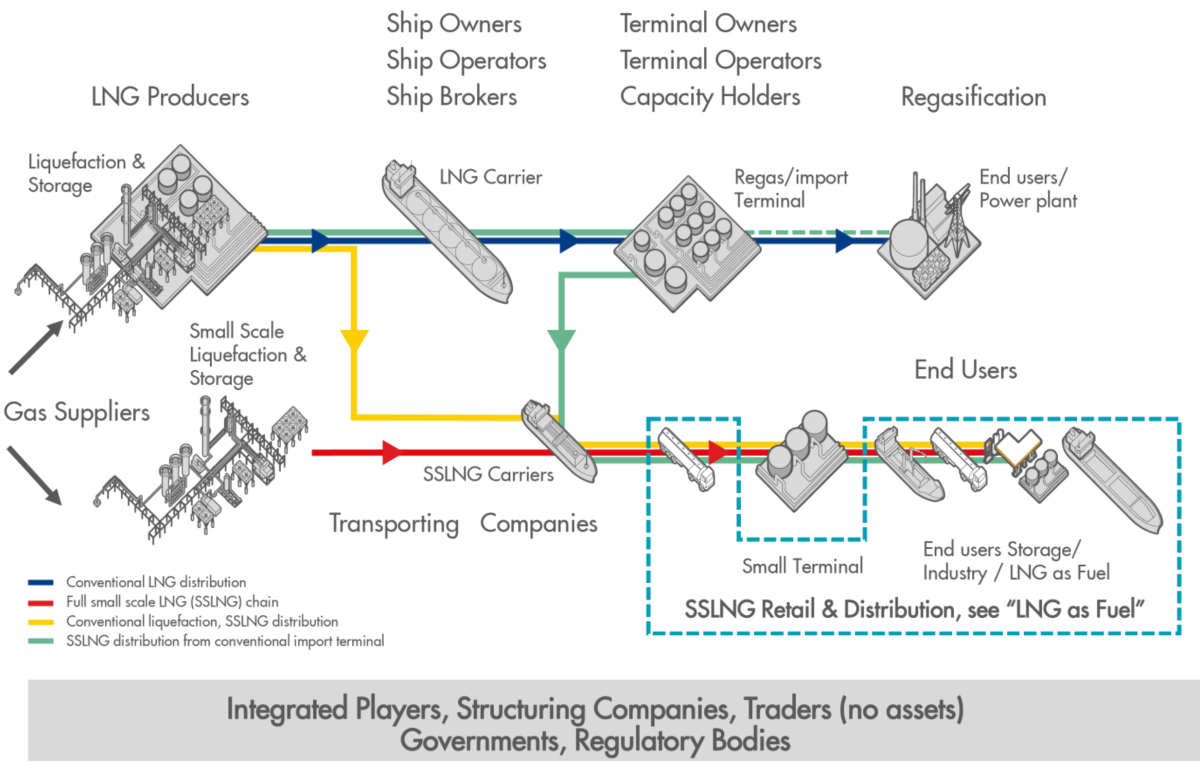


Figure 9 Configurations of the Small Scale LNG value chain. Source: Shell (edited version).

As shown in Figure 9, there are several options to route LNG through the value network. One option is to start at a large scale liquefaction facility loading LNG either into conventional LNG carriers, small scale carriers (up to 30,000 m^3) or trucks/rail cars with end users or distributors as destination. Once loaded on conventional vessels, LNG can then also be transferred to a small or large scale LNG import terminal where it is "break-bulked" and loaded on small scale LNG carriers (up to 30,000 m^3) or trucks/rail cars with end users or distributors as destination. Depending on the choices made for routing the LNG through the small scale LNG value network, several parties will play a role in the process.

Players may be more or less integrated in the value network, according to their business models.

Small scale LNG is a new business in a new market and therefore new parties play a role in addition to the traditional players from the large scale LNG business.

Besides commercial and logistic players, governments and regulatory bodies also play a key role in the value network and have influence on the overall costs. The transportation of LNG by truck and rail and its use as fuel is covered in the report of “LNG as fuel (PGCD - SG2)”, therefore the players in this segment will not be addressed by this report.

In the following section the roles of the parties mentioned in Figure 9 will be described. Some parties can take on several roles at a step of the value network.

Gas suppliers and LNG producers

- The gas supplier own the gas or sells its gas as feedgas to the LNG production facilities
- The LNG producer runs the plant so as to liquefy the gas
- The LNG supplier sells the LNG to off-takers

Example: in China, Xinjiang, the Guanghui Group *(LNG producer)* owns and operates a small scale LNG plant. The gas is supplied from a local upstream oil and gas field (*gas supplier*). The LNG is transported by trucks to a regasification terminal and customers using LNG as transport fuel.

Example: in Norway, Skangass owns the gas once bought from upstream companies (*gas supplier*) and has a tolling agreement with Lyse. Lyse is the owner of the Risavika plant and provides liquefaction service *(LNG producer)* to Skangass. Skangass sells the LNG to downstream parties (*LNG supplier*).

Ship owners / ship operators / brokers

- The ship owner owns the LNGC
- The ship operator operates the LNGC, it has an operating agreement with the ship owner
- The charterer rents the ship from the ship owner at a given rate
- The broker is an intermediary between ship-owners and charterers who use ships to transport cargo.

Example : Gasnor charters a LNGC from Knutsen (ship owner and ship operator). Gasnor is the charterer.

Terminal owner / terminal operators / capacity holders

- The terminal owner owns the terminal and holds a contract with the terminal operator
- The terminal operator runs the terminal and hold a contract with the capacity holder
- The capacity holder owns the molecules and uses the terminal service for handling the molecules

Example : LNG cargo is sold to Dong Energy (capacity holder) and received at Gate LNG terminal in Rotterdam (terminal operator, and terminal owner).

Off takers (regasification and end-users)

- Off takers can be the end users and consumers of gas
- Off takers can be distributors that aggregate volumes and bring it to small consumers

Example : SSAB in Sweden is an end user of LNG.

Integrated Players

Large LNG producers may have capacity all through the value chain. Examples are the international oil companies that supply the gas, produce the LNG in their own facilities, ship the LNG to downstream destinations, break large quantities into smaller portions and sell the LNG to larger downstream end users, like the heavy industry that has no grid connection. They usually own assets in the chain. LNG traders, for example, can also have positions all through the value chain via positions in the commodity (as LNG supplier), selling the commodity to end users. This can be complemented with a position as capacity holder in a large or small scale terminal and as a charterer of LNG carriers. Traders usually do not own the assets in order to maintain enough flexibility for their trades.

Government / regulatory bodies

These parties influence part of or the complete small scale LNG value chain through regulation of the gas markets or as customer of a local LNG receiving terminal. Regulatory bodies may manage security of supply for the country, determining the accessibility and tariffs in a specific country. In such a situation, usually the transmission system operator (TSO) of a country is responsible for the execution of security of supply. In many countries the gas markets (energy markets) are subject to a regulatory regime, limiting the earnings of an LNG facility (especially when it is connected to a national gas grid).

5.2 Interactions in the Value Network

Figure 10 and Figure 11 provide two typical examples of the interactions among the main value chain players and typical chains. Below an example typical for the Chinese market.

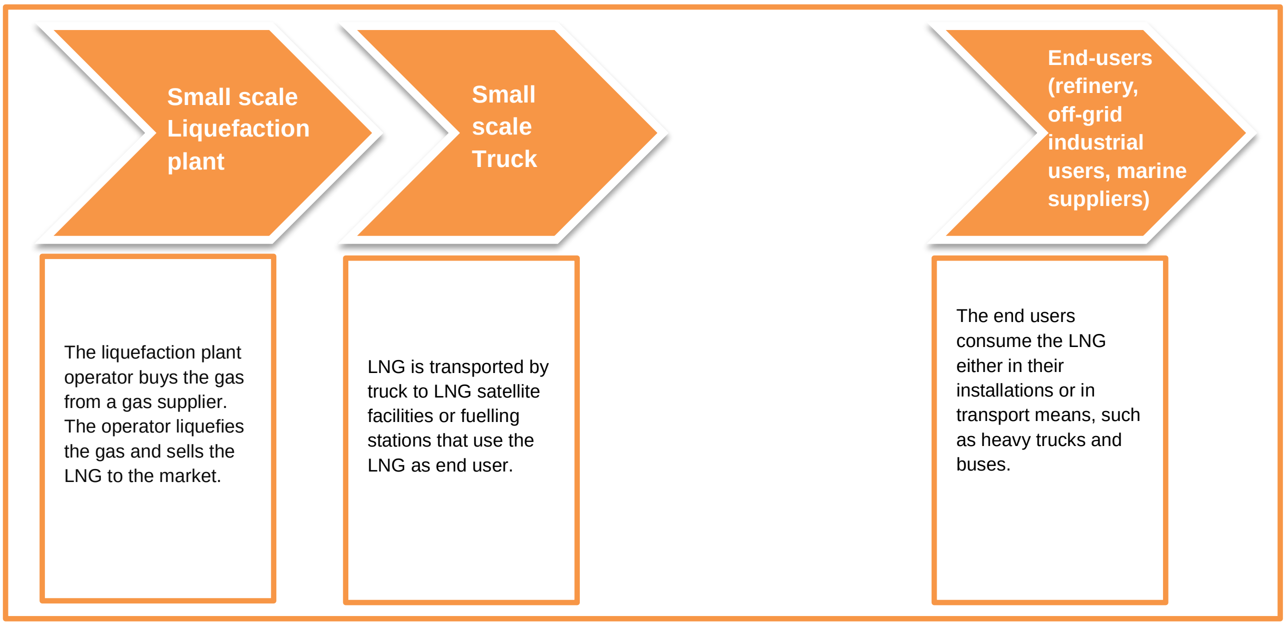


Figure 10 Small scale liquefaction plant and transportation by small ships/truck/rail to small scale terminals/ regas. Source: Vopak.

Figure 11 describes the supply chain around the GATE terminal in Rotterdam to Nynåshamn in Sweden.

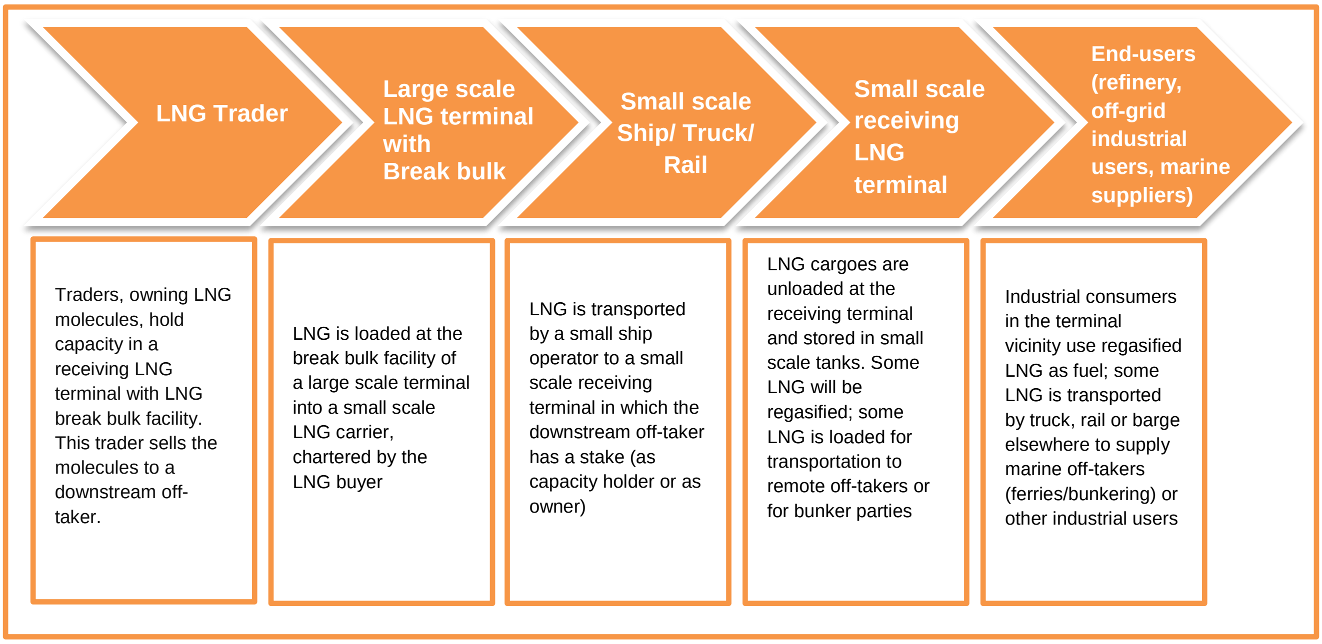


Figure 11 Small scale liquefaction plant and transportation by small ships/truck/rail to small scale terminals/ regasification. Source: Vopak.

The actual interactions will vary according to market dynamics and regulation. Existing configurations consists, for example of small LNG schemes being supplied by large-scale projects with break-bulking facilities, e.g. Northern Europe. Other consists of small liquefaction plants, fed by either stranded gas supplies, e.g. Ecuador or pipeline gas, e.g. China.

6 Technology

Small scale LNG technology is generally perceived to be a very interesting area because the small scale allows faster deployment of new technologies and lower capex hurdles for “learn by doing”. Whereas in conventional LNG production, more than 80% of the world capacity uses C3MR technology, a broader portfolio of liquefaction technologies is used in SSLNG. On the other hand, to remain cost effective, small scale relies on modular and standardized systems and specific technologies rather than optimizing the most effective ones. For SSLNG import terminals, the variety of technology is not as broad as in SSLNG production.

The typical main technology elements in SSLNG are:

- Production
- Storage
- LNG transfer systems
- Transportation
- Regasification and Import terminal

The elements are discussed further in the subchapters below.

6.1 Production

The “small’’ LNG business started with the first commercial liquefaction plants in the early 1940s were peak-shaving facilities with a capacity of around 0.002 mtpa in the US. In1964, the first base load LNG plant started up in Arzew, Algeria (three trains with a total capacity of 1 mtpa). In 1969, the Kenai LNG plant in Alaska (2 trains of 0.75 mtpa each) came online and then Marsa El Brega in Libya (2 trains of 0.75 mtpa) shortly after. The SSLNG liquefaction capacity has been rapidly growing over the last decade. See Appendix J for a comprehensive and illustrative list of SSLNG plant examples worldwide.

6.1.1 Layout

As in the conventional scale LNG chain, natural gas is liquefied in order to reduce its volume for an efficient transportation. The building blocks of a SSLNG production site are very similar to the conventional scale projects. Following is an overview of the main process steps and some considerations on how the layout can be optimized to reduce costs.

Natural gas is initially channelled through a feed gas receiving and metering station, which consists of pressure control, followed by liquid and solid knock-out and separation and finally temperature and pressure control and metering station. Then the gas goes through the treating blocks: acid gas removal, dehydration and mercury removal. The purpose of these blocks is to eliminate impurities (respectively CO_2, H_2S, H_2O and Hg) which would freeze at the cryogenic temperatures reached in the liquefaction unit and would have a negative impact on the equipment performance or even damage it.

Depending on the feed gas composition and demand consideration, an LPG/condensate export unit might be included to monetize the heavier, and more valuable, components of the feed.

The on-spec gas can then be liquefied in liquefaction unit itself, followed by the storage and loading section. In the remainder of this chapter, the technical details of each of these building blocks will be discussed and the main differences with the conventional LNG business are highlighted. The reduced size and complexity of the plant, compared to a conventional plant, potentially allows reduced construction times and project schedule.

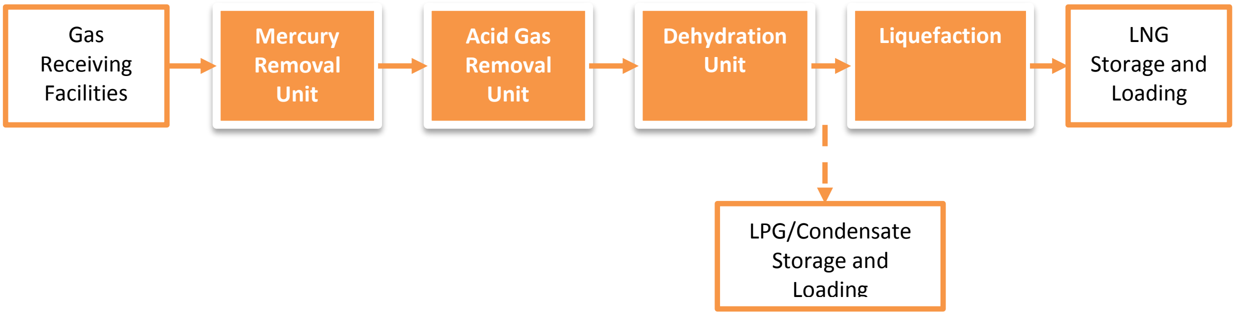


Figure 12 Typical SSLNG LNG plant simple block scheme. Source: Kogas.

6.1.2 Treatment

Like in the conventional LNG business, liquefaction of natural gas in small scale requires a few pre-treatment steps. These process steps help to avoid operational disturbance of the downstream cryogenic plant section and/or ensure that the LNG product meets defined quality requirements (e.g. impurities, heating value, Wobbe index, methane number). In many cases, where pipeline gas serves as feedstock to the liquefaction facility, pre-treatment is less demanding and complex compared to the conventional LNG business. Depending on the natural gas composition at plant inlet, mercury, carbon dioxide, water, heavy hydrocarbons and nitrogen may have to be removed. Mercury is usually separated by adsorption on sulphur impregnated carbon, molecular sieves (silver doped) or metal sulfides . CO_2 is typically removed by a physical wash process with an amine solution. In case the CO_2 content is low, an adsorptive type process may also be applied. Dehydration is done with molecular sieves as adsorbent.

Heavy hydrocarbons are removed after partial condensation of the feed gas utilizing a part flow of the refrigerant cycle. Rejection of nitrogen can be accomplished by simply flashing the LNG before storage. However this simple process step causes a significant content of methane in the nitrogen tail gas. In case this methane rich stream cannot be utilized within the liquefaction plant or routed to plant battery limit, a separation column will have to be applied. This device allows producing an almost pure nitrogen stream that can be released to atmosphere. Some technology suppliers managed to integrate heavy hydrocarbon and / or nitrogen removal steps into their liquefaction processes, which minimizes additional investment, an aspect of particular importance in small scale LNG. An example is shown in Figure 13. In conventional LNG plants removal of heavy hydrocarbons and nitrogen is usually performed in a dedicated process unit upstream of the natural gas liquefaction.

6.1.3 Liquefaction

Two main liquefaction process concepts are currently employed for liquefaction at this scale: expansion cycle processes and single mixed refrigerant processes. For both types of these basic process concepts, some technology providers are also offering an additional pre-cooling step/cycle.

The expansion cycle processes utilise open or closed loops with single or multiple pressure level expansion of nitrogen, methane or a mixture of both gases. The isentropic expansion of the gases provides the necessary cooling duty to liquefy the natural gas.

Single mixed refrigerant (SMR) processes use a different mixture of light hydrocarbons (C1 to C5) and nitrogen that is partly condensed at ambient conditions and then – after throttling to lower pressure - used to cool the natural gas feed stream. An in-depth comparison of the most dominating process technologies in small scale liquefaction for capacities between 30 ktpa and 300 ktpa can be found in (T. Kohler and M. Bruentrup & R.D. Key and T. Edvardsson, January 2014.). A wide range of aspects is covered to evaluate which process – a single cycle, multistage mixed refrigerant or a dual nitrogen expander - is the best choice for which type of application. The authors demonstrate that both process concepts lead to very similar capital costs for installed plants. The differentiators are therefore operating costs and operability.

While for projects with expected high annual operating hours near design plant load, typically found in base load and peak shaving applications, the SMR technology outmatches the nitrogen expander technology with lower operating cost due to higher process efficiency. The downsides of the SMR process, namely reduced part-load capability and longer start-up time are of minor importance in these fields of application.

The nitrogen expander cycle is the preferred liquefaction technology for applications with low annual operation hours and a wide load profile, e.g. as found in boil-off gas reliquefaction. The short start-up time as well as the wide part-load capability and efficiency of the nitrogen expander cycle outbalance the higher specific operation costs, which are of less relevance due to the typically low operation hours in these applications. The typically higher operational expenditures of the nitrogen expander technology may be less pronounced for projects in remote areas, where the purchase of make-up for some refrigerant components of the SMR process (C2 to C4) will be more costly than in well-developed regions.

The pre-cooled MR process using propane as the pre-cooling refrigerant is the most commonly installed process in base load LNG plants reflecting that the pre-cool system is advantageous at higher capacities. For small liquefaction capacities, there are to date only very few pre-cooled processes installed.

Figure 13 The 440ktpa LNG plant at Guanghui, China. LIMUM® - CWHE Process with integrated N2-Removal. Source: Linde Engineering.

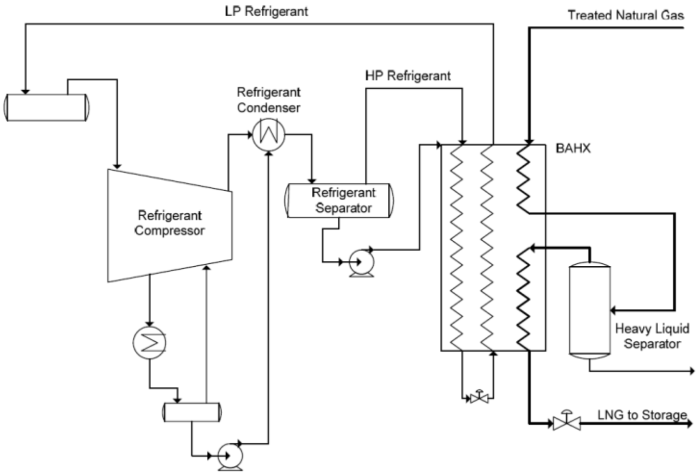
Table 2 displays a list of active technology providers for each of these methodologies. There are specific technology providers out of the conventional ones, with specific and patented processes conceived for this size of projects. It is required to obtain licenses from these technology providers.

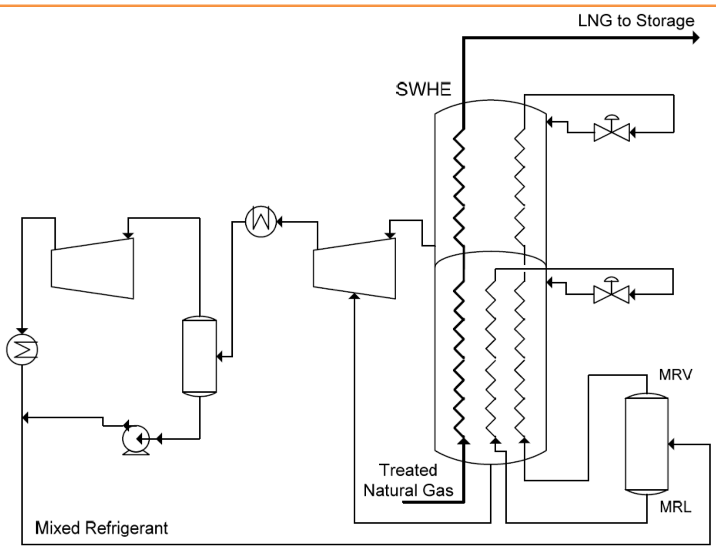
Technology	Refrigerant Type	Process	Company
Mixed Refrigerant Cycle Technologies	SMR	PRICO AP-M LiMuM SCMR Single MR KSMR	Black & Veatch APCI Linde Kryopak Chart KOGAS
	Precooling + SMR	PCMR OSMR	Kryopak LNG Limited
Expansion Cycle-based Technologies	Single Refrigerant Expander (SRE)	Single/Dual N2 Expander NDX-1 OCX	Various licensors Mustang Mustang
	Precooling + SRE	C3 Precooling N2 Expander OCX-R Niche LNG	APCI Mustang CB&I Lummus

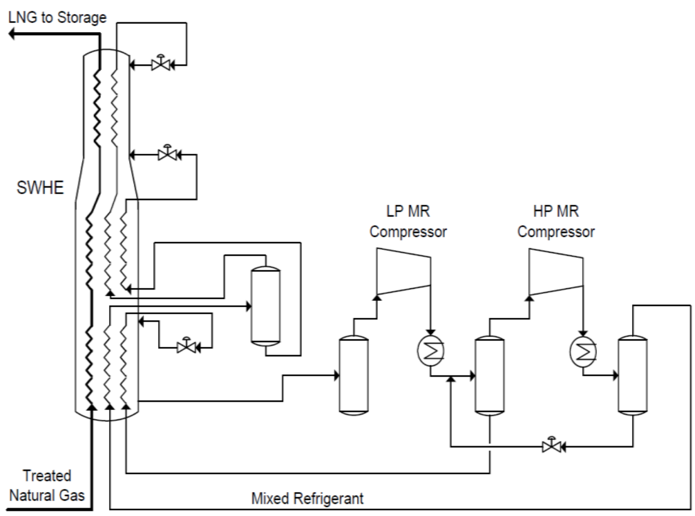
Table 2 Main SSLNG liquefaction technologies, processes and suppliers. Source: Shell.

Following is an illustration of the small scale LNG processes from different technology providers that are already applied and in operation at various small scale liquefaction plants. Additional process concepts that are proposed by various technology providers, but not yet commercially applied in several projects can be found in Appendix F.

<table>
<tr><th>Technology</th><th>Simplified Process Scheme</th></tr>
<tr><td>PRICO (Poly Refrigerated Integrated Cycle Operation)

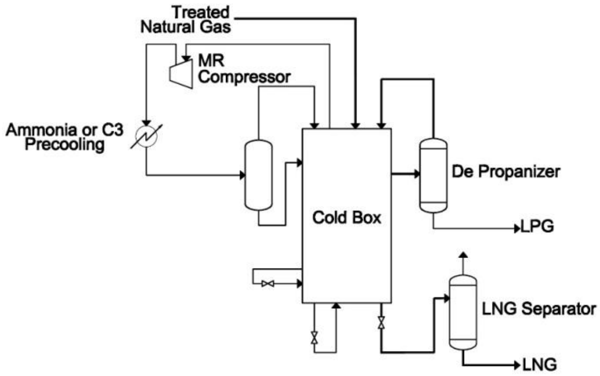
Company: Black & Veatch
Refrigerant: MR
MCHE: FPHE</td><td>
</td></tr>
<tr><td>AP-SMR

Company: APCI
Refrigerant: MR
MCHE: CWHE</td><td>
</td></tr>
<tr><td>LiMuM
(Linde Multistage Mixed Refrigerant)

Company: Linde
Refrigerant: MR
MCHE: PFHE or CWHE</td><td>
</td></tr>
</table>

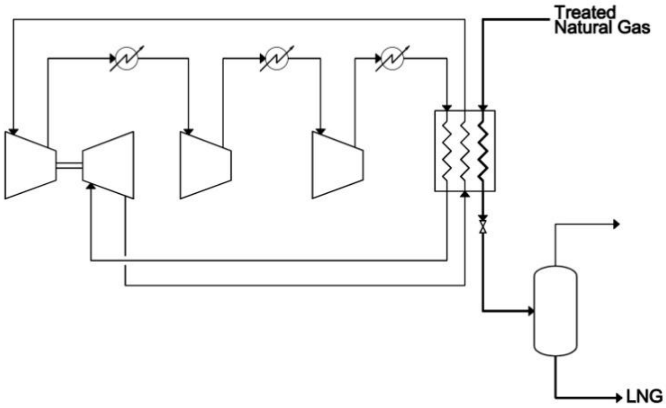
PCMR

Company: Kryopak (Salof)
Refrigerant:
Precooler: NH3 or C3
Liquefier: MR
MCHE: PFHE



Single-/Dual N2 Expander

Company: Various
Refrigerant: N2
MCHE: PFHE



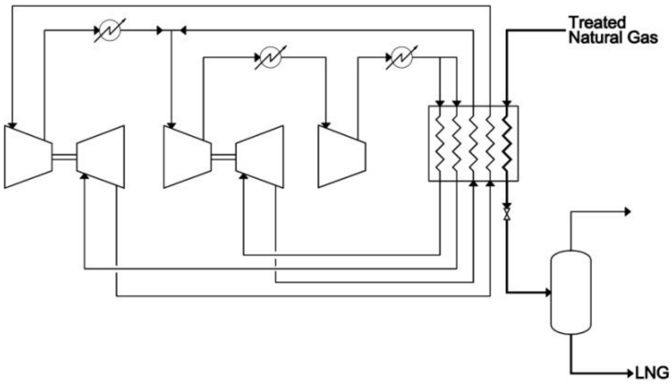


Table 3 Typical SSLNG liquefaction schemes in operation. Source: Kogas. Ref: Enrique Dameno Garcia-Cuerva, Federico Sanz Sobrino (IGU 24 World Gas Conference, 2009). A new business approach to conventional small scale LNG and Silvia Pérez , Rocío Díez, (IGU 24th world gas conference, 2009). Opportunities of monetising natural gas reserves using small to medium scale LNG technologies.

6.1.4 Main Equipment (incl. Manufacturers)

This section provides an overview of the core equipment utilized in the liquefaction processes listed above. The main heat exchanger, in which the cool down and liquefaction of the natural gas takes place, is either a plate-fin type heat exchanger (PFHE) or a coil wound type (CWHE). While expander cycle processes typically only apply PFHE, the SMR type processes apply PFHE at smaller and CWHE at larger liquefaction capacities. The typical application range, including pros and cons for both type of heat exchangers are given in Table 4.

Cryogenic Heat Exchanger	Pro's	Con's	Typical plant liquefaction capacity range (t/d)	Manufacturers (examples)
Plate-fin heat exchanger	• Low cost per unit area • Complex stream arrangement possible • Readily available from several qualified suppliers	• Expensive manifolding for larger plant capacities • Limited acceptable temperature gradients	20 - 800	Chart, Fives Cryo, Linde, Kobe Steel, Sumitomo
Coil wound heat exchanger	• Large heating surface per shell • Tolerant against thermal shocks • Good part load behaviour • Fixing of single tube leakages within moderate down time	• Proprietary equipment • Only one shell side stream possible	> 400	APCI, Linde

Table 4 Cryogenic Heat Exchangers. Source: Shell.

Three main types of compressors can be considered within the small scale liquefaction plant: reciprocating, screw type and centrifugal. The main characteristics and typical capacity range are illustrated in Table 5.

Compressor Type	Characteristics	Typical plant liquefaction capacity range (t/d)
Reciprocating	• Small capacity • Reduced availability • Inexpensive	<20
Screw Type	• Medium capacity • High reliability • Insensitive to composition	20-100
Centrifugal	• Medium to large capacity • High reliability • Optionally integrally geared	20-3000

Table 5 Compressors types for small scale applications. Source: Shell.

In terms of compressor drivers, the alternatives are electric motors, steam turbines and gas turbines. They differ mainly in terms of optimal capacity range, but also in terms of availability and tolerance to nitrogen content in the fuel gas. The main characteristics of each of these drivers are illustrated in Table 6.

Driver Type	Characteristics	Typical plant liquefaction capacity range (t/d)
Electric motor	• Requires stable grid • May require NRU • High availability	20-3000
Steam turbine	• Good match in (coal) chemical plants with HRSGs • May require NRU • High availability	100-3000
Gas turbine	• First choice in remote areas • Sink for N2 rich fuel (max. 20-30 vol-% N2) • Reduced on-stream time (maintenance)	400-3000

Table 6 Compressor Drivers Options for SSLNG applications. Source: Shell.

6.1.5 Utilities

In the same way as conventional LNG facilities, the small-scale LNG plants require a number of utilities to enable the proper operation of the main process units. In addition the plant needs to be embedded in a suitable infrastructure providing feedstock, product outlet and accessibility for personnel and material. Many small scale LNG facilities benefit from the opportunity to use existing infrastructure (e.g. harbor, jetty, access roads, electrical infrastructure, water treatment, work force accommodation, administrative buildings), which lowers the specific costs of the overall project in comparison to the conventional LNG business.

Most existing small-scale liquefaction plants run their main rotating equipment on electric power. Usually no dedicated electric power production as in the conventional LNG business is installed, but the plant is connected to the public grid. This has to be suitable to take the additional load, which sometimes is a challenge in less developed regions. In this case and/or if cheap natural gas is available, the main refrigerant cycle compressor may be driven by a gas turbine and/or electric power may be produced with gas engines. In rare cases, a steam turbine may be utilized as a driver for the main compressor, for example if excess steam is available from an upstream coal gasification for substitute natural gas production, like in a few Chinese projects.

Heating is typically provided by a hot oil cycle that includes a hot oil heater operated with fuel gas taken from tank return gas or feed gas. Provided that hot water or steam is available in the vicinity of the plant, it may be utilized as alternative heating medium.

Cooling of certain process steams is mainly done by air cooling. If a suitable cooling water source can be made available at battery limit of the plant site, this medium may be taken into consideration as an alternative cooling agent.

Instrument air, plant air, utility nitrogen, utility water, demineralized water, firefighting water are other utilities that are usually required in small scale LNG facilities. Simpler means for providing these utilities may be applied in the small-scale business, e.g. making use of a liquid nitrogen tank instead of producing the nitrogen at site as in the conventional LNG business.

For small scale liquefaction plants based on a mixed refrigerant cycle, make-up components (e.g. ethane or ethylene, propane or propylene, butane, pentane) are required. While in conventional scale LNG plants these components are typically produced in a dedicated process unit, small-scale LNG plants buy these from nearby petrochemical facilities.

Depending on pre-treatment process steps installed, adsorbents/chemicals, e.g. molsieves, amine and anti-foam agent may be required.

6.1.6 Production Cost

Capital Expenditure (CAPEX) requirements are obviously on average significantly lower for SSLNG plants, but on a $/tonne per annum basis they are not necessarily more competitive than the large scale LNG business. Small-scale plants lack benefits of economies of scale of the larger projects, but due to their minimal size and relative simplicity, there is a lower need for on-site infrastructure (such as independent power generation) and specialized equipment. A modular model for LNG has been developed especially for the emerging small scale LNG market with the objective to offer a plant with lower CAPEX and shortest execution time ideally targeting the specific needs of small-scale LNG distribution chains. The upside of modularization is the possibility to choose cost effective manufacturing locations of the modules (for example Asia). The downside is added project management and EPC complexity, cost of transport from the manufacturing site to project location and the use of more structural steel (to be able to transport the modules). Another cost mitigation method is standardization, which gives an upside on purchasing large volumes of materials and eventually flawless designs. Another great benefit of small-scale LNG applications is the rapid response time between project concepts sharing and turn-key plant delivery.

Measures taken to reduce Operating Expenditure (OPEX) for small scale LNG production facilities are the use of unmanned facilities and multi-disciplinary staff. Especially the use of unmanned facilities can significantly reduce OPEX.

CAPEX in unit rate is typically defined as a cost per tonne of LNG per annum. The unit rate in $/tonne per annum basis depends on many factors and can differ for the same throughput factor, depending on location, off-site scope, etc. A typical range observed for 0.05 – 1mtpa LNG SSLNG plants is from 350$/tonne per annum LNG (for example in China) up to even 1500$/tonne per annum in other parts of the world (i.e. Europe, Australia). Typical large scale plants often range between 400 – 1200 $/tonne per annum. Important aspects when benchmarking plants is a clear definition of the scope covered. For example, the liquefaction part is typically only 25 - 40% of the total cost, product storage, piping, civil works and infrastructure make up the majority of the remaining cost.

6.2 Storage and Boil Off Gas

In small scale LNG, typically more different types of storage and boil off gas (BOG) solutions can be found than in large conventional scale. Pressurized storage (range 3 – 10 barg) is typically seen in SSLNG only. Also, this opens up more possibilities to contain BOG rather than (re)liquefying or depressurizing it.

The subchapters below provide a description of storage and BOG management.

6.2.1 Storage Tank Types

Typically the range of storage capacity for SSLNG lies from 500m^3 to 5,000m^3, with prevailing pressurized storage tanks. Above 5.000m^3, conventional technologies prevail. The amount of floating storage units (FSU) are increasing as well. They can be equipped with a regasification unit (FSRU).

In SSLNG there are different types of tanks in operation:

- Pressurized
  - Spherical tanks
  - Bullet tanks
- Atmospheric tanks
  - Flat bottom
  - Bullet tanks
- Floating storage (FSU)
  - Inside hull storage (typically atmospheric storage)
  - Pontoons (can contain pressurized storage bullets)

Table 7 provides an overview of the (dis)advantages of the typical SSLNG storage tank types.

Mode	Tank type	Advantages	Disadvantages
Pressurized	Bullet Tank	Savings on BOG management Saving possibly on pumps Pre-fabricated (= fast track)	Lower Safety Factor Limited storage capacity
	Spherical Tanks	Higher capacity than bullet Saving possibly on pumps Pre-fabricated (= fast track)	Limited storage capacity Lower Safety Factor
Atmospheric	Flat bottom	High Safety High capacity	Expensive Long item to build
	Bullet Tank	Pre-fabricated (= fast track) Less expensive	Limited storage capacity
Floating	LNG carrier	Flexible in location, re-use possible	Expensive
		Pre-fabricated elsewhere	Marine berth / jetty / quay and ship-shore interface scope required

Table 7 Overview of typical SSLNG storage type tanks. Source: Total.

The offshore (FSU) storage tanks are described in the Shipping chapter 6.4.1.2. The onshore storage tanks can be of different integrity levels:

- Single Containment (SC), single integrity level
- Double Containment (DC), double integrity level
- Full Containment (FC), full integrity level

In a SC tank, the outer wall is made of non-cryogenic steel. In a DC tank, the outer wall is non-cryogenic steel but there is a storage pit or wall that can contain the LNG during a spill. In a FC tank, the outer wall is from cryogenic steel and if the inner wall leaks, the vapours are contained. Single containment tanks are not allowed by EN-1473 or NFPA 59A, see chapter 7.2.

Whether it deals with small scale or not, sizing storage relies on good sense, and the following rules are applied as much as possible:

- Size will be chosen so as to receive the integrality of the cargo delivered by the ship
- Size will be therefore in the same order of magnitude as the size of the ship carrying LNG
- The carrier ship type and size will be chosen so as to have a reasonable frequency of delivery (provided that waterways and/or road are available for that purpose).
- Thermodynamic state of LNG (cold or warm according to customer possibilities to adjust or accept LNG temperature).

Regular consumption of LNG and aging are constraints specific to LNG which impact the sizing of the infrastructure, irrespective of the size/capacity (large or small). Due to its cryogenic specific aspects it is difficult to store LNG longer than several weeks without liquefying it. Very simply, pressurized tank options offer the possibility to save money on BOG management expenses, and often make it possible to save time in installation. However, a pressurized system will not be a good option if the customer needs cold LNG, unless a concept is applied where liquid nitrogen is used to subcool the LNG if required. In a first approach, a facility of capacity below 0.2 mtpa could grossly rely on a pressurized tank, and on atmospheric for capacity above 0.2 mtpa.

6.2.1.1 Pressurized Bullet Tanks

This class of tanks offer the possibility to hold pressure during a given time, therefore relieving the need to manage the LNG boil off gas like in any conventional terminal.

Basically if the LNG is delivered cold, a storage tank of this type can contain BOG for one or two weeks before the next delivery that will help to recondense the BOG in the receiving tank (LNG used to refill is pumped and therefore slightly subcooled which helps to recondense). The LNG offtaker of that tank might get a rather “hot” LNG.

Cooling the BOG is possible instead of letting the pressure rise, but it is less simple and probably more expensive.

Pressurized tanks currently have a maximal size of 1.200m^3, but there are developments that will allow larger volumes. They display the great advantage of being manufactured in factory saving time and money (a tank of this type is manufactured in circa 6 - 18 months - excluding installation work). The modularity is another advantage, allowing construction at different locations.

Above 1.200m^3, several tanks have to be installed, multiplying connections with LNG piping. Their evaporation rate is limited by the size of the tank (as it is proportional to wet surface). Pressurized tank farms typically rarely go above 5.000m^3 from a total capacity storage point of view.

Below in Figure 14 and Figure 15 bullet types tanks are shown.

Figure 14 2000m^3 horizontal tanks in Jaen, Spain. Source: HAM Enagas.

Figure 15 Horizontal and vertical pressurized tanks at Møsjoen (5000m^3) and Titania (250m^3), Norway. Source: Gasnor AS (Shell).

6.2.1.2 Pressurized Spherical Tanks

Onshore spherical tanks are reported but there are very few cases, see Figure 16.

Figure 16 LNG Plant, Kwinana, Australia. 61ktpa with Spherical Storage. Source: Linde Engineering.

6.2.1.3 Atmospheric Flat Bottom Tanks

Atmospheric cylindrical tanks are usually built on site, and usually take 2 - 4 years to be built at larger scales. They are usually emptied at the top. Their performance from an insulation point of view is very good.

Conventional cylindrical atmospheric tanks are hardly competitive with pressurized tanks for small size (usually below 4.000m^3). These tanks cannot withstand pressure and need to have a BOG management system (see chapter 6.2.2 on BOG management)

However, some atmospheric tanks can be as small as approximately 2.000m^3, see the full containment double steel walled tank in Figure 17. A full containment concrete tank is on the right.

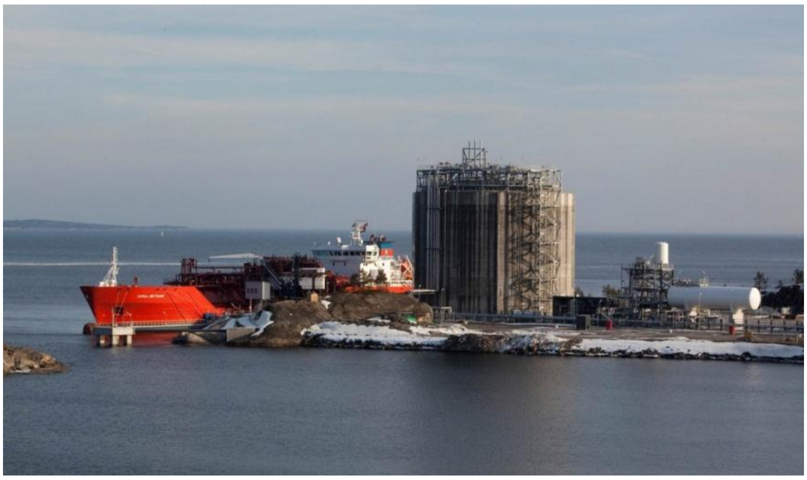


Figure 17 On the left a 2.000m^3 FC atmospheric steel tank, built by Linde (AGA). Source: Gasnor AS (Shell). On the right a 20.000m^3 FC tank by AGA, Linde in Norway. Source: Linde Engineering.

6.2.1.4 Atmospheric non-cylindrical tank

Relying on the LNG ship industry experience, some other type of small scale storage tanks are under development. These new concepts integrate features of atmospheric tanks but some strengths of pressurized tanks, such as modularity/flexibility and prefabricated modules. First trends show that these systems could fill the gap in the range considered too big for pressurized tanks and too small for cylindrical atmospheric tanks.

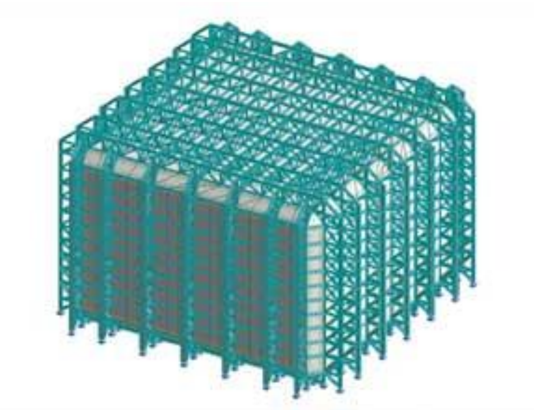


Figure 18 Atmospheric Non-cylindrical tanks (Prototype). Source: Bunkering Solution GTT France (public domain).

Some development is also ongoing regarding the possibility of holding a little more BOG (however this features is studied for safety purpose and not day to day BOG management purpose).

6.2.1.5 LNG Storage Cost

Very few cylindrical small sized tanks are competitive, and the smallest are circa 10.000m^3 if built in concrete for the outer shell. Cost is really local content related for this type of tank. Cost wise, the comparison between a pressurized tank and an atmospheric tank should take in consideration the

BOG management associated investment. But the choice relies not only on tank size, but also on storage duration: a BOG management system offers longer storage duration capability.

A FC atmospheric tank of 28.000m^3 could cost 60 million $, compared to a 170.000m^3 tank which costs 135 million $(Jr, July 19, 2013). The typical cost range observed currently is 800 – 3,000 $/m^3 for SSLNG storage, with lower cost per m^3 when increasing capacity. Pressurized tanks are in the lower range.

6.2.2 BOG management

Boil off gas (BOG) is a typical LNG storage related issue compared to other hydrocarbon fuels. Due to heat ingress, mainly the lighter parts of the liquefied gas (N2, CH4, etc) boil off.

Typical boil-off rates are 0.1-0.5% per day in storage due to heat ingress. Additional BOG is formed when the LNG leaves the piping that boils back to the tank when heat ingress from cooling down the pump and heat generated by the pump and vapour return from loading activities.

By removing boil-off gas (recondense/ reliquefy/ sent out), pressure and temperature are kept the same. If boil-off gas is not removed, pressure builds-up and – if not managed – would eventually lead to the opening of pressure relief systems. When boil-off gas is removed to maintain the pressure level, the methane number decreases because the LNG gets heavier. This is important for LNG as fuel customers because most engines require a minimum methane number to prevent knocking.

If not removed, boil-off gas can be contained under pressure. Pressure will be decreased by emptying the tank and/or refilling it with sub cooled LNG recondensing BOG. BOG is an important aspect in the LNG supply chain that must be taken into account during the complete design, execute and operate phases.

The BOG management required at various supply chain stages depends mainly on the pressure build-up that can be allowed in the supply chain from liquefaction to end-customer. Large LNG customers are mostly energy consumers/producers (like regas to power plants) using atmospheric storage (pressure slightly above 1 bara). Often the LNG is taken-off from these facilities in a gaseous form. Hence the large scale LNG supply requires significant BOG management all over the chain.

Small customers like LNG for transport or small regas facilities can use pressurized storage. In this case different (less) BOG management is required to manage the pressure to be below max operating pressure at the customer.

The BOG management system (removal) will help to keep LNG colder. LNG cold stored under atmospheric pressure can be delivered to any type of customer. LNG stored under pressure (therefore warm) can only be delivered to a customer that has the same type of pressure storage unless the BOG has been removed before.

For small regas customers using pressurized storage, pressure-build up (by a PBU) can be a positive upside because there is no need for a LNG pump. On these terminals, BOG (pressure build-up) can be handled solely by sufficient throughput, sub cooled LNG and vapour collapse (top spray).

BOG mitigations	Mode	Advantage	Disadvantage
Top spray	LNG transfer	Effective, vapor collapse Low cost solution	Requires internals and topfill line + ESD valves Only if pressurized tank
Vapor return	LNG transfer	Relative low cost solution	Contributes to solution, but rarely a standalone solution (depending on flowrate)
BOG compressor	LNG transfer & storage	Allows BOG to be used as fuel gas/ regen gas or re-liquefy Enables to keep pressure constant Can be single BOG management mitigation method	Very costly Maintenance, reliability If subject to high flow changes, need an bypass to flare/vent
Minimize heat ingress	LNG transfer & storage	Effective Many options available (superinsulated/ vacuum/ PUR/ EPS/ PIR) Can be double containment (safety)	Contribute to solution, but rarely a standalone solution (depending on flowrate)
High throughput	LNG storage	Very effective No CAPEX	Contribute to solution, but rarely a standalone solution (depending on flowrate) Most effective with sub-cooled LNG Limited by customer demand and optimal parcel size
Pressurized storage	LNG storage	Allows more BOG accumulation. Could eliminate the need for pumps	Max volume constraints End-customer constraints
In tank Re-liquefying (coil)	LNG storage	Allows BOG intake Enables to keep pressure constant	Requires another cryogenic tank Coolant refilling required

Table 8 Boil-off-Gas mitigation methods in SSLNG.

6.3 LNG Transfer

LNG product outlet from small-scale LNG facilities or storage is typically by loading on trucks. Sometimes a small jetty will be required if loading onto dedicated small LNG vessels is part of the business case.

In any case, marine infrastructure requirements will be less demanding than for a world-scale LNG installation, however their percentage of total cost should not be underestimated. The transfer systems require typically quite some space due to safety distances, which in some environments also requires significant civil work (jetty length, truck plot space). Other equipment items found in the transfer area are safety systems (i.e. gas and fire detectors, ESD panels and firefighting equipment), interface for the crew or truck driver (panels, control rooms), custody transfers (coriolis or flow meters with gas chromatographs) and LNG spill containment. For truck units, small loading arms or hoses are quite common. Typically, 3inch is the largest hose diameter found for truck loading. For SSLNG ships typically hoses are only used if the diameter is below 8inch. For 4inch and larger also often loading arms are available.

The transfer flow can be typically created by pressure build up when using pressurized storage, submerged pumps or external sealless cryogenic pumps. For cooling down the transfer lines and custody equipment before the transfer, a recycle line is required for recycling the initial BOG creation during cool down. In most LNG systems, a purging option (typically N2) to purge out the remaining amount of LNG after the transfer is also present. Alternatively, the lines can be continuously kept cold by LNG recycle flows. Transfer of LNG generates typically some BOG which needs to be handled. When there are BOG compressors, they need to be adequately sized to cope with the fluctuating BOG by LNG transfer.

6.4 Shipping

The difference between LNG small scale ships and large scale is primarily business related and the maximum size for a small scale LNGC is set to <30,000m^3 storage capacity. The smallest LNG carrier currently in use is the one from Seagas, a 167m^3 LNG carrier used as bunker ship in the port of Stavanger. The roles of SSLNG carriers can be different than large LNGCs. Due to the expected growth of LNG as bunker fuel, it is very likely that more LNG bunker vessels will be built in the future. The following purposes are foreseen:

- Small scale LNG transport, inland and coastal, sometimes intercontinental
- Small scale LNG bunker vessel, mainly port based

As the LNG small scale business is growing, the fleet of small scale LNG carriers is also expanding; see Appendix G for existing and future overview of the fleet. The CNG fleet on the other hand is very slowly picking up with only one 2200m^3 ship in the orderbook and no existing fleet.

The use of LNG as bunker fuel is described in the IGU report “LNG as fuel”.

6.4.1 SSLNG Shipping Characteristics

LNGCs are built in line with the IMO’s IGC Code and Class Society rules. The code applies to ships regardless of their size, including those of less than 500 tons gross tonnage, engaged in the carriage of liquefied gases having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8 degree centigrade. Similar to large LNGCs, SSLNGCs normally also use the natural boil off gas from the LNG cargo as fuel for purposes which may include propulsion, electrical power generation or steam generation.

So the rules and regulations don’t differentiate between small and large scale LNGCs. Also, in the safety risks scenarios there are no differences from a methodical point of view. Although there are no design rules differences between large and small scale LNG carriers, the small scale fleet has different characteristics.

6.4.1.1 Manifold

For large LNGCs, a distinction for manifold dimensions is made between different sizes of ships, see the overview of A, B and C below. This comes from the i.e. OCIMF publication Manifold Recommendations for Liquefied Gas Carriers. Small scale fleet ships fall under Category A.

- Category (A) To 60, 000 m^3
- Category (B) 60,001m^3 – 200,000m^3
- Category (C) Over 200,001m^3

LNG		Diameter (in inches)		Horizontal (in meters)	
		Liquid	Vapour	Horizontal Minimum	Horizontal Maximum
	A	12	8 / 12	2.5	3.0
	B	16	12 / 16	3.0	3.5
	C	16 / 20	12 / 16	3.5	4.0

Table 9 Manifold Recommendations for Liquefied Gas Carriers. Source: SIGTTO

It shows that there is no difference for manifolds and rules for ships below 60,000m^3 (yet).

Figure 19 Small scale pressurized tank LNG ships (1100m3 Pioneer Knutsen & 7500mr Coral Methane), Source: Shell, Knutsen and Anthony Veder.

6.4.1.2 Cargo containment

One distinctive difference between small and large scale LNG carriers is the allowable pressure in the ship. The small scale ships often have IMO type C tanks (pressure vessels). So far, recent small LNG carriers are all designed with type C tanks.The larger ships have atmospheric tanks:

- IMO type A (max 0.7barg)
- IMO type B (MOSS, max 0.7barg)
- membrane (max 0.7barg however currently 0.25barg on most LNGCs)

The advantage of type C tanks is that there is limited or no need for boil-off gas management within specified duration. I.e., the BOG will be contained within the tank resulting in rise of pressure and temperature until it reaches the designed relieving pressure of the tank. Disadvantages of Type C pressure tanks are reduced volumetric efficiency, limited tank size and increased weight compared with atmospheric tanks. See below some of the main characteristics of LNG in pressurized and atmospheric conditions;

- Pressurized storage: Heat In – Boil Off Contained, LNG Temperature -126°C, density 363kg/m^3
- Atmospheric storage: Heat In – Boil Off Out, LNG Temperature -162°C, Density 423kg/m^3

6.4.1.3 Marine Transfer system

Another difference is the LNG transfer rate. Typical loading rates are in the region of 200m^3/hr for an 1000m^3 vessel up to 2000m^3/hr for a 30,000m^3 vessel. Various items including liquid flow rates, typically 7 – 10 meter per second, dictate the transfer rate.

Where marine transfer arms are generally used for conventional onshore terminals (despite LNG hose transfer becoming a credible option), for transfer of small quantities of LNG with low flow rates, hoses can also be used. The advice from ISO-28460 – “Installation and equipment for liquefied natural gas — Ship-to-shore interface and port operations” is that hoses should be used if the total volume of LNG in the hose transfer system does not exceed 0.5m^3 and the length of hoses doesn’t exceed 15 meters.

6.4.2 Safety Developments in SSLNG Shipping

The main typical small scale LNG shipping developments are on the following safety aspects:

- Low costs emergency shut down (ESD) interlinks between shore and ship (SIGTTO)
- Small emergency release systems and emergency release couplings (often simpler such as drybreak coupling instead of power emergency release couplings)

Not all the safety equipment is currently (easily) available for the small scale LNG market. A challenge for the small scale industry is to find quality equipment that is cost-effective.

In addition to this, safety distances during loading/unloading activities are being discussed. This is a seriously challenging item considering the necessity for some operators to bunker during commercial operations or in more populated areas.

Due to the nature of small scale LNGC operations, additional challenges also exist for example when there is an interface between large scale activities and small scale activities (especially when there are considerable differences in freeboard, jetty height, fender sizes, loading rates, see below). This necessitates the need of fit for purpose training and certification for the staff.

Figure 20 Small Scale Vessel Coral Methane 15.000m3 and Artic Princess conventional LNG carrier at Gate Terminal. Source: GATE Terminal, Rotterdam via Vopak.

6.4.3 Shipping Cost

A small scale LNG carrier's investment cost is higher per ton LNG compared to large scale LNG vessels. For example, the investment cost (CAPEX) for a 215.000 m^3 LNG carrier is approximately 250 million $, a 135.000 m^3 LNG carrier is approximately 170 million $, a 28.000 m^3 LNG carrier is approximately 80 million $ (Bourgeois, 20th September 2011). This relates to a capital expenditure for small scale LNG ships to be typically in the range of 5 - 15 thousand $/ton, while large conventional shipping is 2 – 5 thousand $/ton.

The operational expenditures of small scale LNG carriers are also higher per tonne LNG per mile compared to large scale LNG vessels. In absolute, SSLNGCs are staffed with smaller crews and engine and cruise speed are usually much lower than conventional LNGCs. Also, when suitably designed, small scale LNGCs will incur reduced costs for mooring and port activities (like tug boats, pilots, shore handling, etc). In situations where the ship crew operates the LNG satellite regas terminals, there are associated cost savings on the terminal side as well. However, per ton LNG per mile the operational cost are higher (i.e. lower economy of scale). Most of this cost is reflected in the day rate for a ship. Typical daily rate cost for SSLNG carriers are 30.000$/day for a 15.000 m3 cargo vessel and 35.000$/day for a 20.000 m^3 (excluding fuel cost).

A cost summary is given in Table 10.

Size m^3	CAPEX million $	CAPEX thousand $ per m3	Typical crew number	Typical harbor cost (Europe)
215.000	250	6	30 - 35	100 – 200k$ per visit
135.000	170	6.5	25 - 35	75 – 150k$ per visit
28.000	80	15	15 - 20	25 - 40k$ per visit

Table 10 Typical investment cost for LNG carriers. Crew and harbour cost source: Shell historic STS database

Bigger ships have higher GRT or require larger number of tug boats etc. so for any port on like for like basis – reduced tug boats / services will reflect in lower costs for small scale LNG carriers per visit.

6.5 Small Regasification and Import Terminals

Historically, regasification/import terminals grew big so as to reduce cost of regasification handling massive quantity of LNG. To remain a competitive solution, simpler processes/technologies have been used most of the time inspired by the industrial gases industry in their design (e.g. air vaporizers). This has been also possible because the footprints of small scale vaporizers are acceptable for the volume of LNG handled.

There are onshore and offshore (floating) terminals. Currently there are no small scale LNG floating terminals (FSU's or FSRU's) that fall within the definition of small scale of this report.

6.5.1 Specific features of a small regasification/import terminal

The SSLNG terminals often have some specific features that are outlined below.

- Very often, these installations are unmanned. In the few cases where they are manned, the personnel is reduced to the minimum and they are only on site for maintenance or unloading operations (where in some conventional terminals personnel can reach up to 200 people).
- Most of the small scale regasification plants are built with prefabricated equipment (like in the industrial gases industry) and pre-assembled modules brought directly to site, providing a faster project schedule especially regarding the tank (which is usually the long lead item on a conventional terminal). Portable regas skids are quite commonly used as well.
- In some cases, pressure build up is used in tanks prior to regasification instead of a pump.
- LNG inventory is lower, allowing in most cases scaled safety measures and simpler safety devices, without compromising on the overall plant safety level.
- Maintenance is reduced as there are very few rotating parts and instrumentation.
- Very often the LNG transfer is through a flexible hose, using a dry break coupling as the emergency disconnection system. Boil off gas generated naturally or due to LNG processing is handled in the pressurized tank, until it is condensed with the next subcooled delivered LNG or by utilization of backup liquid nitrogen.
- Air vaporizers are the preferred equipment for their simplicity and the absence of operating expenditures. They are installed in a redundant manner to let vaporizers defrost while others are on duty.

Traditionally, import terminals were built to regasify LNG, but that has changed today. Some of the terminals are being modified to be able to break-bulk, re-load or bunker ships and trucks. See in Appendix H an overview of such terminals in Europe.

6.5.2 BOG options

Some terminals with a capacity below 1 mtpa use conventional technologies found in large scale LNG regasification terminals.

Conventional and specific small scale principles are depicted below for comparison:

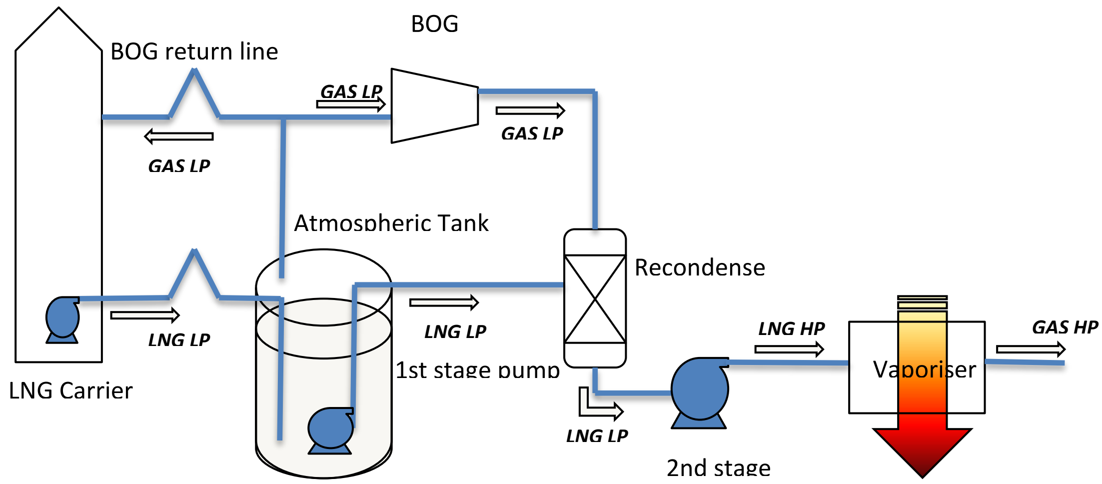


Figure 21 Typical conventional regasification/import terminal. Source: Total, France.

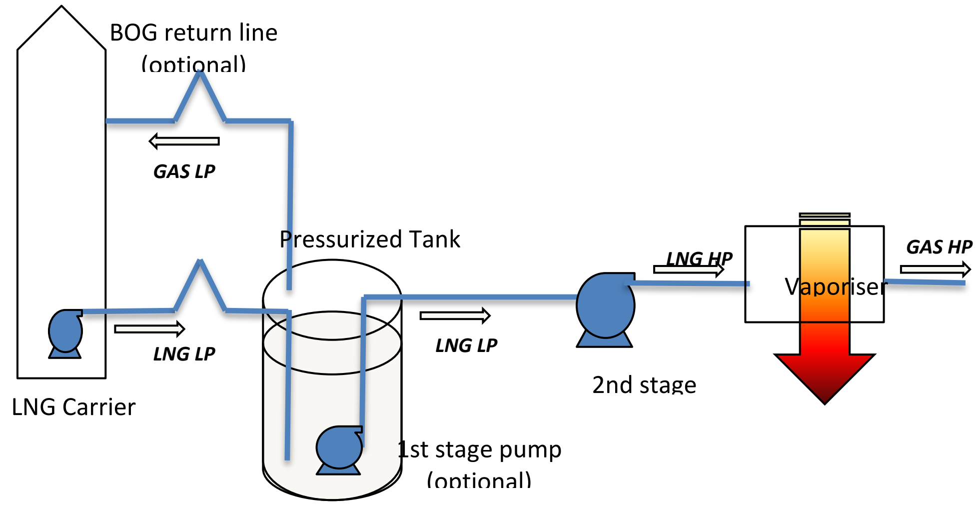


Figure 22 Typical small scale regasification/import terminal. Source: Total, France.

6.6 Logistics

One of the key critical success factors of the (small scale) LNG supply chain is to optimize the associated logistics, because this is a significant part of the capital and operational expenditure. In Figure 3, scale and large scale LNG logistical distribution chains are shown.

The logistics are linked to the final market size. For this case, the SSLNG carrier's fleet would probably be dedicated, at least while the markets are building up.

6.6.1 Logistic analysis and distribution methods

To perform a logistic analysis for a conventional transport by large LNG carrier, the supply chain is further broken down into elements. Each of these elements impacts the overall logistic performance of the supply chain, see Figure 23.

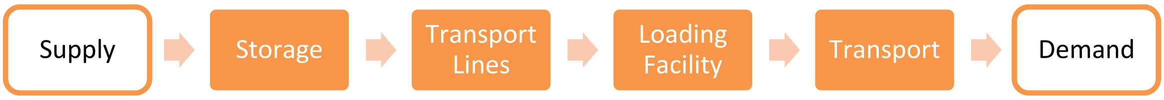


Figure 23 Elements within the logistic supply chain.

Logistic analysis of a small scale supply network can be done in a very similar way. However the logistic behavior of each element in SSLNG can be different, because there is much more distribution flexibility (shipping, trucking, containers), distances are shorter and/or the number of customers is larger. The starting point is obviously the customer demand. From this point, an iterative exercise can be carried out to find out what is the best balance from a cost standpoint between the size of the infrastructures at both ends and the fleet. Some of the main differences between large, conventional LNG and small scale LNG in the elements are given below in Table 11.

Element	Conventional transport	Small Scale transport
Supply	LNG plant	LNG plant, regas & import terminal/ small scale liquefaction plant
Storage	Tanks at LNG plant	Tanks at production/ import & regasification terminal
Transport Lines	Jetty	Jetty, truck loading unit
Loading Facility	Berth	Berth, jetty, ship to ship or truck loading dock
Transport	LNG carriers	Small LNG carrier, LNG trucks, containers and/or trains
Demand	Customers at import/regasification terminal	Customers at small terminals or direct offloading to customers

Table 11 Differences between the conventional LNG and SSLNG logistic elements within supply chain.

6.6.2 Logistic SSLNG characteristics

In SSLNG, distances are typically much shorter compared to conventional LNG, because there is an optimum coverage area for certain production and distribution scales. Endurance of vessel depends on fuel storage vs. fuel consumption per day or per nautical mile. Another consideration is regarding the company policies and the amount of reserve required all the time and also accounting for un-pumpable in the tanks. The typically small scale distribution radii observed are given below in Table 12. For example, a conventional Qmax 266.000m3+ vessel action radius is typically > 20.000 nautical miles (>37.000km), while the max radius for a 7.500m3 is approx. 1.500 – 2.500 nautical miles (2.700km – 4.600km). Onshore (truck) transport limits itself typically to 2.000km (approximately 1.100 nautical miles).

Distribution	Shipping Transport		Truck Transport
	Coastal [nm]	International [nm]	Onshore [km]
Typical action radius	0 – 1.750	300 – 12.500	0 – 2.000 (1.100nm)

Table 12 Typical radius of offshore and onshore SSLNG transport.

Parcel sizes are in the range 20 - 60m^3 per truck and average size is 30m^3 (13ton), (ref GIIGNL). For ships typical parcel sizes are in the range 500 – 30.000m^3. Because the parcel sizes and distribution distances are smaller, the number of logistical movements is much greater than in conventional LNG. With small carriers, bunker ships and trucks there can be 5 - 30 loading/unloading operations on site per day, while in large LNG sites normally a large LNG carrier comes few times a week. A few of the typical differences in logical characteristics between SSLNG and conventional LNG are outlined in Table 13 below.

Large scale/ conventional LNG	Small scale LNG
Small fleet available	Modest fleet available
"Big" ship	"Little" ships and/or many trucks
Big marine infrastructure, tugs (high CAPEX)	Limited size infrastructure (lower CAPEX), small berths and jetties, truck loading units
Cost effective per m^3 transported	Higher delivery frequency
Lower berth occupancy	

Table 13 Differences between conventional LNG and SSLNG shipping.

6.6.3 Challenges for Small Scale LNG logistics

When developing a logistical model for SSLNG, the following challenges typically arise:

- Cost

The distribution costs for SSLNG are relatively high compared to other (hydrocarbon) products due to the cost of the cryogenic equipment required.

- Low priority for small ships

Especially for SSLNG shipping, berthing priority for small ships is often lower than large ships; hence the probability of demurrage is higher if they do not have 'dedicated' jetties. This is not different to other hydrocarbon products but more to other conventional large LNG vessels.

- Limited fleet size

The SSLNG shipping fleet is still relatively small compared to other more mature (hydrocarbon) markets. In Table 14 below, the current size and orderbook is given.

Shipping capacity & number		
	[kton]	#
Existing	101	24
Planned	145	14

Table 14 An overview of current and orderbook of LNG ships. Source: Clarksons.

There is currently no shipping spot market, almost all SSLNG ships are contracted and built under long term time charter contracts. This means that there is little flexibility as to what ships are available for development of fast opportunities.

7 Safety, Standards and Regulations

7.1 Safety

Even if the diffusion of LNG along the small scale chains is constantly growing all over the world, international technical safety standards require improvement and adaptation in specific areas, especially in operational aspects. Regulations, which are generally supported by technical standards, are not yet developed and formalised except in few countries.

This fact testifies to the difficulty of fitting the complexity and variety of this new branch of the LNG business in a world where conventional fuels and their logistic infrastructures have been firmly established over decades.

There are many barriers to the development of new safety standards and regulations, including:

- The cryogenic nature of LNG. LNG is the first and only cryogenic fuel offered to a large scale market and this implies very peculiar technical issues. For example, no other conventional fuel produces boil off;
- The international characteristics of the LNG market that lead to a need for "global" or at least "regional" standardized interfaces. An example is the newly built small to medium sized LNG carriers, some with pressurised tanks, and others with conventional tanks. Both of them will need to dock at the same terminal, possibly the same as conventional large size LNG carriers;
- The difficulty of integrating new infrastructure into active areas, like ports, often congested, close to urban areas, with possible safety issues, and usually already strictly regulated by local, national or even supra-national laws;
- The need to create a common ground of awareness of the small scale LNG characteristics and potential among industrial stakeholders of different nature (LNG suppliers, technology providers, users), governmental entities and the public. In addition, the number of experts that currently know how LNG can be safely transported, transferred, managed and stored in the small scale environment is limited if compared to the envisaged amplitude of the market and this doesn't help a fast harmonization;
- LNG facilities are often at the interface between offshore and onshore. Marine facilities generally relate to international rules whereas onshore facilities are based on national regulations.
- The global nature of the small scale LNG development. In many countries, pilot projects/initiatives have been developed with success. Each success tends to create local (sometimes "strictly local") know-how that can be conflicting with the know-how developed elsewhere. An example: screwed connections for hoses are widely used but fast connecting couplings are also proposed to the market. Will both standards have to coexist and how?
- As the potential of Small Scale LNG is not yet fully understood and defined, it becomes quite difficult to define some of the necessary standards and the required regulations. For instance, currently no one is now providing a LNG transfer service between vessels during navigation but this kind of operation can be considered usual for conventional fuels; is there a need to start thinking of international standards for this kind of transfer or is it too early?

Even if the size and complexity of the described barriers is quite high, some scattered and initial evolutions have already started. They can be summarized in few lines:

- Development of local and national regulations in the frontrunner countries;
- Supranational/federal interest to create common standards and regulations;
- Interest of certifying bodies in the development of specific guidelines.

The common fundamental factor of these evolution lines is safety.
In the following paragraphs international standards and local regulations will be discussed in general terms and specific cases will be presented from some of the countries that are more advanced in introducing LNG and from other countries where similar efforts are ongoing.

7.2 Technical standards

Watching the recent evolutions in small scale LNG, it can be noted that the development of new technical standards for plants and components and the operative procedures, have been based on the adaptation of standards commonly used in the well-developed large scale LNG industry or in some specific niches as, for instance, the LNG peak shaving plants[1].

A key importance can be attached to the LNG terminals that are becoming the heart of the development of the first small scale LNG initiatives in those regions where such terminals were already operating. In the past two decades, these plants have spread out in all the continents, allowing the local industries and authorities to come into contact with LNG and to build the first nuclei of knowledge. In the producing countries, a similar role is fulfilled by the LNG liquefaction plants.

In this respect, organizations like *The Society of International Gas Carrier and Terminal Operators* (SIGTTO) and the new born *Society for Gas as a Marine Fuel* (SGMF) have an important role in establishing a base level of harmonization.

Another important source of know-how and experience, if not directly of standards and procedures, is the cryogenic gas production and processing industry and, secondly, the wide area of the hazardous substances. Other standards and guidelines are coming from the maritime side of the LNG business: International Maritime Organization (IMO) is very active in producing practical high level guidelines, both on the environmental and safety side.

The International Standard Organization (ISO) is also discussing new draft standards covering the areas of main interest for small scale LNG. Up to now, the approach of ISO has been to target high level guidance and standards rather than developing detailed comprehensive frameworks. Therefore few documents have been issued in its final release but many more are under development in the working groups, as shown in Appendix D.

The Appendix D attached to this document lists a number of international standards, usually not specifically developed for small scale LNG uses, that are at least partially applicable to this new industrial environment and that constitute the basis for any related project.

[1] Mainly the American NFPA 59A and 49 CFR 193 for the United States of America and the European Standards delivered by CEN, the European Committee for Standardization.

7.3 Regulations

The improvement of existing national regulations has been identified as one of the most important challenges for a healthy development of the small scale LNG, by many entities, companies and consultants involved in the start-up of small scale LNG initiatives.

The root reasons for this gap can be linked to the immaturity of the small scale LNG environment and the need for governments to better understand the amplitude and penetration of this new business, also considering the rate of substitution of traditional fuels and the need for a clear picture of the environmental benefits and safety impacts that could be generated by the use of LNG.

Some steps towards the construction of a mature frame of regulations have been taken in some of the most LNG-committed countries and in specific locations such as ports, where the authorities, pushed by the market surge and being in need of managing LNG, started creating operational frames and procedures.

7.4 Regional overview of Standards and Regulations

Here below is a snapshot of the status of standards and regulations[2] in different countries and regions of the world, including some of the main actors.

7.4.1 Asia

China

China regulates its gas market prices by the National Development and Reform Commission (NDRC). Besides a considerable share of domestically produced gas, LNG imports from international markets have grown significantly in recent years. To bridge the gap between low prices for domestically produced gas and LNG imports a reform of the price regime has been ongoing for more than a decade, with accelerated activity in 2013 and 2014. For the impact on the Chinese SSLNG business please kindly refer to the Chapter 'China Case'. The NDRC continuously fixes a ceiling price for LNG and gasoline. During the last years the spread between both fuels has been kept constant in favour of LNG in the order of 20% (on heating value basis). Every new domestic SSLNG liquefaction project needs an approval from the NDRC.

Japan

Japan is one of the first countries to start LNG distribution via truck. LNG truck transportation to a small scale terminal which is called "Satellite terminal" started in 1970 by Tokyo Gas Co., Ltd. Investment-return of pipeline couldn't be expected because the length of pipeline was long although there was little gas demand between the LNG import terminal area and the satellite area. The high construction cost of pipelines and the existing developed highway system have historically helped the LNG small scale business develop in Japan. Japan does not have network of pipelines, but rather relies on the large number of LNG receiving terminals which is approximately 30 terminals at this moment. This large number of LNG terminals as an infrastructure for re-export is another reason to expand the small scale business. There are also LNG distribution routes via small ships and railways.

[2] At the date on which this portion of the report was finalised (Sept. 2014).

LNG distribution via small ship is effective for the wholesale market in this island country and LNG railway transportation applies in snow prone areas to avoid road traffic accidents during winter due to freezing roads.
LNG import terminals are regulated by the “Gas Business Act”, “Electricity Business Act” or “High Pressure Gas Safety Act” depending on the main business area of the company which runs the terminal. Whereas the sale and distribution of gas via pipeline in Japan must comply with the “Gas Business Act”, LNG distribution via truck or via railway is required to comply with the “High Pressure Gas Safety Act”. The “High Pressure Gas Safety Act” regulates production, storage, sale, import, consumption and disposal of high pressure gas in order to prevent incidents, though there are some exemptions in the case of being regulated by other Acts. The “Ship Safety Act” and other relevant regulations for ship transportation are applicable for LNG distribution via ship and, it is necessary for the ship transportation to obtain consensus with Japanese coast guard and other stakeholders in some expert safety port committee

India

The manufacture, sale, import, export, use and all the activities pertaining to explosive and inflammable materials in India, including LNG, are regulated by the following acts:

- Explosives Act 1884
- Petroleum Act 1934
- Inflammable Substances Act, 1952

The Petroleum & Explosives Safety Organization (PESO) is the statutory authority in India, working under the Ministry of Commerce & Industry, that is responsible for the administration of the above mentioned acts. PESO is in charge of framing national rules concerning public safety in collaboration with the Oil Industry & Safety Directorate (OISD) and other bodies, harmonizing Indian with international standards and of evaluating new technologies that could find application in hazardous areas.

Established in 1986, OISD has been pursuing its mission to assist the oil and gas industry of India in achieving the highest standards of safety. This will help to ensure maximization of occupational safety and minimize loss of life and property.

The directorate has also been engaged in formulating and implementing a series of self-regulatory measures aimed at removing obsolescence, standardizing and upgrading the existing standards to ensure safe operation. Standards like OISD-194, NFPA59A, etc. are being followed for implementing LNG terminals. OISD publications in no way supersede the statutory regulations of PESO or Chief Controller of Explosives (CCE), Factory Inspectorate or any other statutory body which must be followed as applicable.

Static & Mobile Pressure Vessel (SMPV) rules are being followed for LNG satellite stations using pressure vessels and also for the LNG road tanker movement in India. The SMPV rules are currently under revision. A separate chapter on LNG storage and road transportation is under preparation.

Iran

No LNG is currently available in Iran, the first conventional sized liquefaction plant is under construction and peak shaving plants are under study. A proper national standard from IPS (Iranian Petroleum Standard: Section C of IPS-E-PR-360), is ready to be used for LNG applications, also in the small scale area.

Thailand

In Thailand, both a conventional LNG Terminal, located at Map Ta Phut Industrial Estate and a Small Scale LNG liquefaction plant, located in Sukhothai province are operated. The Small Scale LNG plant has been developed in order to create additional value to the associated gas produced locally, answering a requirement for emissions reduction.

The two plants follow the same international safety standards such as NFPA59A (Standard for the production, storage and handling of LNG), ASME, API, NFPA52 (Vehicular Gaseous Fuel system code). For Thailand standards, the LNG facilities are verified for compliance with Engineering Institute of Thailand (EIT standards) and Thailand Industrial Standards (TIS).

With regard to statutory regulations, the Department of Energy business, the Ministry of Energy is responsible for promoting the use of natural gas and energy efficiency, supervising on competition of investment in the energy business by providing a standard of quality and security of natural gas and promoting the developmental system of the clean energy and environment.

The Ministry of Industry of the Kingdom of Thailand is responsible for the promotion and regulation of Industries including LNG such as Industrial Act 1969, Ministerial Regulation in the part of gas industries 2006, National Environmental Protection Act 1992, Ministerial Notification for Emergency Preparedness and Response Drill plan in industries 2009 and so forth.

7.4.2 Russia

Russia

Increasing world demand for small scale LNG gives Russia opportunities to develop its export business, especially in the European region, where natural gas has been considered as a transportation fuel because of a rise in petroleum products prices and new stricter standards on emissions. According to various estimates, the European small scale LNG demand may reach more than 16 million tons per year by 2030 only for use in transport (i.e., for vehicles and for the purpose of bunkering in the North and Baltic Seas), and can be close to 30 million tons per year in the case of a tightening emissions of ships in the Black Sea and the Mediterranean.

The main segment of small scale LNG consumption for Gazprom is the foreign market, principally Europe, and this market is still in its infancy. However, Gazprom is working on opportunities to strengthen its position in this segment.

Currently there are six units of small scale LNG production in Russia with a total capacity about 68,000 tons per year, and 13 more plants with total capacity 926,000 tons per year are planned to be constructed.

7.4.3 Europe

European Union

The European Commission published a proposal for a directive on the development of alternative energy infrastructures in the EU in January 2013. The European Commission recognized that the lack of infrastructure and of common technical specifications is an important barrier to the introduction of alternative fuels like hydrogen, electricity and natural gas. If adopted (expected 2015), the proposal would oblige Member States to build up a minimum infrastructure for alternative fuels like LNG: 139 ports should be installed by the end of 2025 for maritime ports and by the end of 2030 for inland waterway ports and LNG refuelling points.

Besides developing alternative fuel infrastructure networks, the EC proposal also focuses on the implementation of common technical specifications. For instance, the proposal prescribes basing any further standardization activity for LNG refuelling points for waterborne vessels, on ISO TC67/WG10.

Up to now[3], the agreement still needs to be approved by the Parliamentary Transport Committee as well as the Parliament itself and, later, by the European Council.

France

France has been operating an LNG import terminal since 1964 and is among the first countries to operate an LNG terminal in the world. Historically, LNG infrastructure in France has been limited to large import terminals, shaping the content of the applicable LNG standards. From a standard standpoint, documentation and guidelines have wide enough scopes to cover design of small scale as well, and France relies generally on ISO or EN standards. However, a lack of standards is identified for LNG retail and when LNG is used as a fuel for transportation. Europe is promoting the use of LNG as the cleanest hydrocarbon fuel and has asked the European standardization body to fill the gaps.

From a regulation point of view, tools are in place to oversee the activity of small scale LNG. Existing regulations are under the umbrella of the Seveso Directive for the storage capacity of liquefied hydrocarbon gases over 6 t; specific regulations cover smaller storage facilities. LNG plants are generally registered as Installation Classified for Environmental protection (*ICPE*) as requested by the code of environment, according to their capacity (from 6t to 50t, it has to be declared to authorities; from 50t to 200t, it has to obtain an authorization based on safety studies; and above 200t it also has an extra emergency response plan involving authorities).

However, work is in progress to adapt the current texts as they stem from LPG, and new guidelines are under elaboration to optimize the field of application.

Another set of regulation may apply depending the design: Pressurized Equipment Directive for example.

For marine LNG, France's policy is derived from European policies.

Germany

In Germany, a quite similar initiative as in the Netherlands (see below) named MARITIME LNG PLATFORM e.V. was initiated in 2014.

MARITIME LNG PLATFORM e.V. is an association of companies, ports and initiatives targeting cleaner shipping through the use of LNG and the significant reduction of emissions, such as SOx, NOx, CO_2 and particulate matter. The platform's activities are defined by a specific roadmap:

- In 5 years: the operation of at least an additional 50 ships in German ports using LNG and at least five German ports ensuring the supply of LNG for the shipping industry.
- In 3 years: at least an additional 250 ships per year supplied by shore power through LNG on the water side.
- A specific and measurable reduction of SOx, NOx, CO_2 and particulate matter based on the above measures.

Italy

[3] September 2014

In Italy, the Ministry for the Economic Development is leading the constitution of a national strategic plan with the support of other ministries and the main national industry organizations. The plan shall include, among other aspects, the definition of a specific regulatory framework for the development of a complete LNG distribution infrastructure network; a specific law and the necessary application rules are expected to be in force in 2015.

In 2014 a national decree was approved setting a 0.1% sulphur limit for navigation in the Italian waters of the Adriatic and Ionian seas (including EEZ), starting from 2018. This is seen as an opportunity to support the small scale LNG development. The enforcement is conditional on the approval of the other EU member states facing the same seas, namely Slovenia and Croatia, of equal or higher limits.

The Netherlands

The Netherlands has been one of the most active countries in promoting the new business area of small scale LNG. The interest has gradually grown since 2007, when Gate LNG, a project for the realization of the first Dutch LNG terminal located in Rotterdam, was sanctioned. The terminal was ready to operate in 2011. The physical presence of LNG in the country has led to many initiatives in the area of small scale LNG, like the "Wadden and Rhine Green Deal", a national act that in 2012 led to the constitution of the "Nationaal LNG Platform", an operating body where governmental authorities and national economic and technical operators meet in order to agree a coordinated policy. The main target of the "Nationaal LNG Platform" is the so-called "50/50/500": by the end of 2015, in the Netherlands and neighboring countries shall operate at least 50 ships, 50 river barges and 500 trucks utilizing LNG as a fuel.

This ambitious target led to the need for additional standards and regulations to complement those already laid down and applicable in the national legislation or based on the European directives and rules.

In 2011, a joint industry project for the Legal and Safety Assessment (LESAS) of a possible small scale LNG supply chain for the Rotterdam area was started. The LESAS project aimed at developing a roadmap towards an optimal small scale LNG supply chain for the Rotterdam area from a safety, commercial, technical and legal point of view based on the long term vision of relevant stakeholders. It included the analysis of the current framework of regulations, codes and standards and the identification of legal aspects related to the design of infrastructures and operative aspects.

Two guidelines containing the regulations to be used by all the authorities, constructors and operators, respectively for vehicle and ship installations, were published in 2013 and 2014 to support the permitting process of LNG installations (PGS 33-1 and 33-2). In 2014, the Dutch legislation was improved in order to enable LNG bunkering operations, ship-to-ship, both for river barges in Seinehaven and for ships in Rotterdam.

Spain

The Spanish Gas System has been a pioneer and a leader in the development of small scale LNG activities and continuously adapting regulation and tariffs to provide new LNG logistic services as well as collaborating actively on the development of LNG as a fuel.

In particularly, Spain started the promotion of LNG small scale activities in 1970, through LNG trucking regulations which have allowed the development of this business: the Spanish system is at the moment the international leader on LNG truck loading with around 40,000 LNG trucks reloaded per year, equivalent to 13 LNG reloading standard vessels, supplying both internal and European demand, in France, Italy, Switzerland and Portugal.

Regarding security standards in Spain, the transport of dangerous goods is governed by the ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road) since the accession made on October 19, 1972. Furthermore, LNG trucking regulation is included on the general gas regulation: Royal Decree Law 949/2001, Royal Decree Law 1434/2002, Technical Manager of the System Rules (NGTS) and its Detail Protocols (PDs). The service was fully operational since 1970, but in 2012, the Spanish Manager of the System approved a new detailed protocol of LNG trucking to improve operational details.

Regarding maritime small scale activities, a regulated service of reloading operations in place since 1997 is governed by Royal Decree Law 949/2001, Royal Decree Law 1434/2002, Technical Manager of the System Rules (NGTS) and Detail Protocols number 5 (PD-05) "*Procedure for gauging the amount of energy offloaded from methane tankers*" and number 6 (PD-06) "*Operating standards for offloading methane tankers*".

As the interest for new LNG services has gradually grown, a debate between the Ministries, the General Manager of the System and the shippers has been launched through a working group to develop these services on the Spanish Gas System. This group will debate the new LNG services such as maritime and train small scaling, transhipment, and new LNG uses as a fuel: bunkering, automotive (NGV) and train fuelled by LNG. The result of this working group is expected to be a revision of current Detail Protocols that could eventually lead to a new specific Detail Protocol for maritime small scaling activities or amend current ones.

Regarding the new LNG uses as a fuel, important initiatives have been launched such as Ports of the State bunkering development, and the foundation of a sectorial Iberian association to develop maritime and automotive LNG use, Gasnam. With AENOR, this association is developing regulations to promote the service under current security and logistic standards. Other challenging projects are "LNG Blue Corridors" and "GARnet". Both will deploy LNG and L-CNG stations along different corridors in Spain and Europe for heavy duty vehicles.

Norway

Currently, Norway has the largest SSLNG business in Europe. Although Norway is the largest gas producer and exporter in Europe, many locations in Norway itself are not connected to the main grid. To supply these with gas many satellite LNG import and regasification terminals are available to supply industries and local distribution networks. In Norway, one large LNG plant is located in the north (Snohvit) and five mini and small LNG facilities along the west coast.

In addition to the NORSOK standards, the EN-1473 is being used for LNG production facilities. For terminals, TS/EN 13645 (Installations and equipment for liquefied natural gas) are typically used. In general, the European standards (PED) are used.

In Norway, there are currently approximately 50+ ships sailing on LNG and within a few years it expected to grow to 80+ ships using approximately 200 - 300 ktpa of LNG. The use of LNG as a marine bunker fuel is stimulated by the Environmental NOx-Agreement 2008 – 2017. This is an Agreement between 15 Norwegian business organizations and the Ministry of the Environment which was approved by the ESA (Efta Surveillance Authority) in Brussels in 2008. The NOX fund receives an amount per NOx kilogram emitted and the fund invests in NOx reduction methods for domestic emission only, i.e. shipping between Norwegian ports.

Turkey

Turkey has two conventional sized LNG terminals with a total storage capacity of 535.000m³ on the western coast line which increases expectations for the business. These terminals are mainly used as a backup plan for the country which is nearly 100% dependent on imported fuels such as natural gas. Additionally, the implementation of the terminals launched a small scale industrial LNG business in late 2005 which is still a good low cost fuel alternative for hotels, industrial zones, asphalt plants etc. where natural gas grid is not available.

Despite the fact that there is not any "detailed" legislation in place other than the Primary Natural Gas Law, existing industrial LNG installations are designed, implemented, operated and separately controlled by governmentally accredited engineering companies. These accredited companies work under related standards such as TS/EN 12300 (Cryogenic Vessels – Cleanliness for Cryogenic Service), TS/EN 13458/1,2,3 (Static Vacuum Insulated Tanks), TS/EN 13645 (Installations and equipment for liquefied natural gas), TS/EN 1160 (LNG Terminal & Equipments – General LNG Specifications), PED & TPED (2010 / 35 / EU) and secondary regulations like "Fire Protection Legislation of Buildings" and "Safety Guidelines for Employees".

On the other hand, the use of LNG for vehicles has been pending due to lack of regulations both on stations' and OEM vehicles' side.

The Turkish Standards Institute, which is the main body for design and implementation of country standardization, is a "P" member in the ISO committee that is currently working on developing PC 252 (ISO EN 16923 & 16924), which will be the main standard for LNG & CNG implementations for fueling LNG and CNG vehicles in retail sites.

As a conclusion, LNG as fuel is drafted in the Primary Natural Gas Law and is currently waiting for approval of the council of ministers. It is expected to be discussed by the parliament in 2015.

7.4.4 South America

Brazil

The oil and gas sector in Brazil is regulated by Federal Laws 9478/1997(Petroleum Law) and Federal Law 11909/2009 (Gas Law). The National Petroleum Agency (ANP) is responsible for regulating, contracting and supervising the activities of exploration, development, production, refining, distribution and retail. The activities of production, regasification and distribution of LNG follow the provisions of several administrative ordinances issued by the ANP which establish that such activities should be in conformity with federal and state technical standards, including the standards issued by the Brazilian National Standards Association (ABNT), the National Institute of Metrology (INMETRO) and the recommendations from the OIML (International Organization of Legal Metrology), ISO (International Organization of Standardization), and NFPA 59-A (National Fire Protection Association).

Federal Decree 7382/2010 establishes that any facility designed to liquefy natural gas or regasify LNG requires the authorization of the ANP.

ANP's Ordinance 118/2000 regulates the activities of construction, operation and distribution of LNG, which should follow the provisions of ABNT and INMETRO standards for the transportation and handling of materials, the road transportation of hazardous materials, the construction, installation and inspection of trucks and truck bumpers.

The construction of GNL distribution stations and transportation should also follow municipal, fire brigade, environmental and road authorities' regulation, when applicable.

ABNT Standard NBR 15244/2005 establishes criteria for the design, building and operation of vehicular natural gas filling system from liquefied natural gas (LNG).

Ecuador

In Ecuador, the National Institute of Technical Standards (INEN), published the Technical Standard INEN 2590/2011 establishing the procedures for the transport of LNG by road and by sea.

Colombia

Federal Decree 0381/2012 establishes the competency of the Ministry of Mines and Energy to regulate the gas industry in Colombia and, in particular, to set up the administrative and technical rules concerning the exploration, production, transportation and exportation of natural gas. The Ministry issued a draft technical ordinance to regulate the design, siting, construction, and operation of LNG production and liquefaction facilities in Colombia.

The ordinance will also cover aspects related to the formation of personnel involved in LNG activities. It has been put forward for a consultation process but it was not clear whether it has been published already. The activities should observe an extensive list of international standards – from which a sample : NFPA 10 till 5000, ACI 301 till 376 and API 6, 625 etc.

Bolivia

The Supreme Decree No. 2159/2014 approves the Technical Regulations for the Design , Construction, Operation, Maintenance and Abandonment of plants Liquefied Natural Gas - LNG Regasification Stations and establishes that the Regulatory Agency will develop the regulation necessary for the implementation and application of the technical regulation. The technical regulation will not be applicable to small LNG containers nor to LNG transportation vehicles.

7.4.5 North America

United States of America

Small scale LNG projects serving the wholesale market are covered separately by economic and infrastructure regulatory proceedings and safety reviews for facilities serving the *interstate* (across U.S. state lines) natural gas trade, LNG export of U.S. domestic supplies and imports, and *intrastate* (within a U.S. state) natural gas trade. This complex regulatory structure is in following with the U.S. federal system, which makes clear distinctions of jurisdictional boundaries based on the markets served.

LNG projects that serve the U.S. *interstate* natural gas pipeline system are under the jurisdiction of the U.S. Federal Energy Regulatory Commission (FERC), which rules on pipeline tariff applications and associated contracts and involves "stakeholders" (including natural gas local distribution companies and direct pipeline gas consumers) through formal administrative proceedings. Economic and operational issues faced by stakeholders are the main subjects of these proceedings. The LNG facilities themselves are reviewed for compliance with safety requirements administered by the U. S. Department of Transportation, Pipelines and Hazardous Materials Safety Administration (PHMSA) and codified under U. S. Title 49, Code of Federal Regulations Part 193 (49 CFR 193). FERC safety staff, working with PHMSA staff, have a significant role in these PHMSA proceedings and approvals.

With respect to LNG facilities serving import and particularly export functions, economic regulation under the Natural Gas Act is implemented by the U. S. Department of Energy (DOE), Office of Fossil Energy and governed by U. S. “public interest” criteria, especially for exports to countries not covered by Free Trade Agreement (FTA) treaties. PHMSA and FERC staff play important roles in evaluating safety and environmental compliance, respectively, with 49 CFR 193 serving that the fundamental set of safety requirements and U.S. environmental requirements administered by the U.S. Environmental Protection Agency (EPA) guiding environmental siting and operational requirements

LNG projects serving *intrastate* markets are governed by state laws and regulatory schemes, which in many cases and approaches follow the federal interstate regulatory model. However, safety requirements at the state level may more closely follow National Fire Protection Association (NFPA) Standard 59A rather than 49 CFR 193.

7.4.6 Recommendations on Safety, Standards and Regulations

The very high safety level and respect of the environment reached by the traditional LNG industry, including transportation by sea and by road, have been built over 50 years of experience and provide a solid base for the development of the small scale segment.

The number of already existing standards developed for the industry of LNG, for cryogenics and marine LNG and the efforts of some governments in building regulatory frameworks are helping realise the first infrastructure and integrated “pilot” chains in different countries across the globe, where new functionalities and safety can be tested and adapted.

Further efforts will be necessary, as the widespread diffusion of LNG in anthropized contexts requires a strict respect of appropriate standards and rules as well as proper training levels of all the involved personnel, even of the smallest operator.

The standardization authorities and the governments, with the necessary support of all the stakeholders, should therefore operate in order to make possible an approach to the diffusion at a lower scale of the LNG, both normalized and robust.

Some recommendations can be delivered in order to help pursuing such targets:

- Fast finalization of the technical standards necessary for the small scale LNG segment, is a priority. A slow maturation process can harm the sound market development and increase the safety risk;

- Governments and supranational entities must provide a timely and favourable legal framework to the industry, allowing for the construction of the basic infrastructure in accordance with the best technologies available and therefore guaranteeing to keep high the safety level;

- Safety and design philosophies for the small scale LNG segment must learn from the previous experiences in LNG, like, for instance, small scale LNG in Spain, and import the good experience and reliability of the traditional LNG industry, in order to keep the level of robustness of the technical choices high;

- Sharing of LNG safety learning’s in the industry.

- Specific standards for training and fostering the adoption of certification accreditation mechanisms for the personnel working in Small Scale LNG facilities and on transportation means must be created, overtaking the standards currently adopted for the personnel working with hazardous materials;

8 Outlook and Conclusions

The small scale LNG business is set up for growth in the near future, linked to the key drivers of price spread between natural gas and oil and the environmental benefits of SSLNG as fuel for heating, transportation and power generation.

In terms of growth regions, the economic and environmental advantages of using SSLNG as fuel are driving the expansion of SSLNG in China, to fight pollution in urban areas. The number of SSLNG plants recently built or planned in China is significant and expected to reach 20 mtpa by 2020. The SSLNG production industry is very dynamic in North America, driven by increased gas availability from shale gas production and the price differential between natural gas and oil products. Stricter regulations on the marine sector will boost the use of SSLNG as bunker fuel in Europe (Scandinavia, Baltic and NW Europe). In Latin America the key drivers are the monetisation of stranded gas supplies and the need to reach remote consumers. Significant small scale regas capacity is already present in China, Japan, Spain, Turkey and Norway and continues to grow to service remote local areas and fluctuating consumption profiles.

Further growth of the SSLNG market will be achieved in a market with clear incentives, whether by economic drivers or by robust environmental regulations.

Enabled by significant technical developments in small scale LNG, the SSLNG industry is becoming more competitive and safer. Moreover, improvements to project economics are expected from standardisation and modularisation of production facilities. The SSLNG business opens the possibility to implement more challenging LNG technology concepts more quickly and cost-effectively, which can benefit the conventional large-scale LNG industry as well.

However there are still many challenges, for example, the development of cost-effective supply networks, the stalemate between supply and demand and the lack of worldwide consistent regulatory frameworks, including safety standards. Further growth of the SSLNG network will introduce new challenges, for example in the area of boil off gas management and meeting fuel quality requirements to use LNG as fuel.

An important consideration is the impact of the recent drop in oil prices on the investment decision for natural gas and LNG projects. This is expected to affect the SSLNG business in particular, due to its fast-responding nature and because these projects require large oil/gas price differentials, that may no longer be available in the current oil price scenario.

Historically, the conventional LNG industry has demonstrated a very good safety track record developed along decades of continuous improvement and industry cooperation. The situation for SSLNG is different because the industry expansion with many new players is not coordinated in the same way as in the conventional large scale LNG business and may lag behind in terms of standardisation and establishment of the necessary technical, safety and regulatory framework.

In order to develop the SSLNG business on a worldwide scale, it is important to consider the recommendations below:

- Fast finalization of the technical standards necessary for the Small Scale LNG segment is a priority.
- Governments and supranational entities should put in place a timely and a comprehensive legal framework and fiscal regime for the industry, allowing for the construction of the basic infrastructure in accordance with the best technologies available and therefore guaranteeing an environment conducive to SSLNG investment.

- The sharing of best practice on safety and design philosophies from the conventional LNG business and from existing SSLNG projects, for example, small scale LNG in Spain, will be helpful to maintain high safety and technical standards. The IGU could provide the platform for this, promoting safety standards and best practice within the industry.
- It is necessary to develop specific standards for training and foster the adoption of certification accreditation mechanisms for the personnel working in SSLNG facilities and on transportation modals, mirroring the standards currently adopted for the personnel working with hazardous materials.
- The development of downstream infrastructure and logistics – remote regas facilities, bunkering and trucking stations - is key to building a robust market for SSLNG.
- Further technical development across the value chain is necessary to help bring down costs and to make the industry more competitive and resilient against oil price fluctuations.

The expectation for the small scale LNG business is that the expansion will continue towards 2020, growing towards a 30 mtpa business globally. This growth is predicated on the implementation of a level playing field, with economic incentives and robust environmental regulations, on technology developments driving down costs, and on the sustainability of a competitive price spread between natural gas and oil.

Appendix A. Contributors

We acknowledge the contributions of the Study Group Program Committee D3 members in compiling the various sections of this Report:

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Appendix B. Abbreviations

Abbreviation	Name
ABNT	Brazilian National Standards Association
ANP	National Petroleum Agency (Brazil)
API	American Petroleum Institute
ASME	American Society for Metals
BOG	Boil off gas (vaporizing LNG)
C&P	Contracting & Procurement
CAPEX	Capital Expenditure
CBM	Coal Bed Methane (gas from coal)
CFR	Code of Federal Regulations (US)
CIF	Cost, Insurance and Freight
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
COA	Contract of Affreightment (customer may use the ship part of time)
CSU	Commissioning & Startup
CWHE	Coil-Wound Heat Exchanger (very small tubing exchanger)
DC	Double Containment (tank)
DES	Delivered Ex Ship
ECA	Emission Control Area
EN	European Norm standards
EPA	U.S. Environmental Protection Agency
EPC	Engineering, Procurement, and Construction
ESD	Emergency Shut Down
EU	European Union
FC	Full Containment (tank)
FERC	U.S. Federal Energy Regulatory Commission
FID	Final Investment Decision
FLNG	Floating Liquefied Natural Gas
FOB	Free on Board (ownership changes at loading ship)
FSRU	Floating Storage Regasification Unit
FSU	Floating Storage Unit
FTA	Free Trade Agreement
GATE	Gas Access To Europe (terminal in Rotterdam, The Netherlands
GHG	Green House Gas
H_2S	Hydrogen Sulfide, an acid and toxic gas
HFO	Heavy Fuel Oil (bunker oil for ships)
Hg	Mercury
HSSE	Health, Safety, Security, Environment
ICPE	Installation Classified for Environmental protection (France)
IMO	International Maritime Organization
INEN	National Institute of Technical Standards (Equador)
IOC	International Oil Company
IP	Intellectual Property
ISO	International Standard Committee
LCA	Life Cycle Analysis
LESAS	Legal and Safety Assessment
LNG	Liquefied Natural Gas
LNGC	LNG Carrier
LPG	Liquefied Petroleum Gas
MDO	Marine Diesel Oil (bunker oil for ships)

MGO	Marine Gas Oil
MOSS	Spherical IMO type B LNG tank (design owned by the Norwegian company Moss Maritime)
MR	Mixed Refrigerant
MTPA	Million Tonnes Per Annum
N2	Nitrogen (vapor)
NFPA	National Fire Protection Association (US standard)
NGL	Natural Gas Liquids
NGTS	Technical Manager of the System Rules (Spain)
NOx	Nitrogen Oxides, generic term for NO and NO2. NOx gases react to form smog and acid rain
NRU	Nitrogen Rejection Unit
OISD	Oil Industry & Safety Directorate
OPEX	Operational Expenditure
ORV	Open Rack Vaporizer
PBU	Pressure Build-Up unit
PD	Detail Protocols number # (Spain)
PED	Pressure Equipment Directive (EU)
PFHE	Plate Fin Heat Exchangers
PGS (33)	Publicatiereeks Gevaarlijke Stoffen (Netherlands, Publication range of Dangerous Goods)
SC	Single Containment (tank)
SECA	Sulphur Emission Control Area
SGMF	Society for Gas as a Marine Fuel
SIGTTO	The Society of International Gas Carrier and Terminal Operators
SMPV	Static & Mobile Pressure Vessel
SMR	Single Mixed Refrigerant
SOx	Sulphur Oxides, generic term for SO, SO2 and SO3 and larger. SOx are precursors to acid rain and atmospheric particulates
SPA	Sales and Purchase Agreement
SSLNG	Small Scale LNG
TS/EN	Technical Safety/ European Norm
TSO	Transmission System Operator

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Appendix D. Industry Standards & Regulations

International standards for Design[4]

NFPA 59A- Standard for the Production, Handling and Storage of Liquefied Natural Gas (LNG) 2013 edition
This US National Fire Protection Association standard applies to the location, design, construction, maintenance and operation of all facilities that liquefy, store, vaporise and handle natural gas and deals with the training of personnel involved with LNG.

EN 1473:2007 Installation and Equipment for LNG - Design of Onshore Installations
This European Standard provides guidelines for the design, construction and operation of all onshore liquefied natural gas installations, including those for the liquefaction, storage, vaporisation, transfer and handling of LNG.

EN 1474-1:2008 - Installation and Equipment for LNG – Design and testing of marine transfer systems – Part 1: Design and testing of transfer arms (Being revised as ISO/DIS 16904)
This European Standard specifies the design, minimum safety requirements and inspection and testing procedures for LNG transfer arms intended for use on conventional onshore LNG terminals. It also covers the minimum requirements for safe LNG transfer between ship and shore. Although the requirements for remote control power systems are covered, the standard does not include all the details for the design and fabrication of standard parts and fittings associated with transfer arms.

EN 1474-2:2008 - Installation and Equipment for LNG – Design and testing of marine transfer systems – Part 2: Design and testing of transfer hoses
This European Standard provides general guidelines for the design, material selection, qualification, certification, and testing details for LNG transfer hoses for offshore transfer or on coastal weather-exposed facilities for aerial, floating and submerged configurations or a combination of these. While this European Standard is applicable to all LNG hoses, there may be further specific requirements for floating and submerged hoses. The transfer hoses will be designed to be part of transfer systems (fitted with ERS, QCDC, handling systems, hydraulic and electric components etc…).

EN 1474-3:2008 - **Installation and Equipment for LNG - Design and testing of marine transfer Systems – Part 3: Offshore transfer systems**
This European Standard gives general guidelines for the design of LNG transfer systems intended for use on offshore transfer facilities or on coastal weather exposed transfer facilities. The transfer facilities considered may be between floating units, or between floating and fixed units. The specific component details of the LNG transfer systems are not covered by this European Standard.

BS 4089:1999 Specification for Metallic Hose Assemblies for Liquid Petroleum Gases and Liquefied Natural Gases
This British Standard specifies requirements and test methods for metallic hose assemblies used for the loading and unloading of liquefied petroleum gases under pressure, primarily for road and rail tankers or for ship to shore duties.

EN 60079-0 2009 Explosive Atmospheres
This part of IEC 60079 specifies the general requirements for construction, testing and marking of electrical equipment and Ex-components intended for use in explosive atmospheres. Unless modified by one of the standards supplementing this standard, electrical equipment complying with this standard is intended for use in hazardous areas in which explosive atmospheres exist under normal atmospheric conditions of:

EN 12065:1997 Installations and equipment for liquefied natural gas - Testing of foam concentrates designed for generation of medium and high expansion foam and of extinguishing powders used on liquefied natural gas fires

[4] This list is based on the content of the SIGTTO/SGMF document "Standards and Guidelines for Natural Gas Fuelled Ship Projects"

EN 12066:1997 Installations and equipment for liquefied natural gas - Testing of insulating linings for liquefied natural gas impounding areas

EN 12308:1998 Installations and equipment for LNG - Suitability testing of gaskets designed for flanged joints used on LNG piping

EN 1252-1:1998 Cryogenic vessels - Materials - Part 1: Toughness requirements for temperatures below -80°C

EN 12567: 2000 Industrial valves- Isolating valves for LNG – Specification for suitability and appropriate verification tests
This European Standard specifies the general performance requirements of isolating valves (gate valves, globe valves, plug and ball valves and butterfly valves) used in the production, storage, transmission (by pipeline, rail, road or sea) of LNG.

EN 13645:2002 - Installations and equipment for LNG – Design of onshore installations with a storage capacity between 5 t and 200 t
This European Standard specifies requirements for the design and construction of onshore stationary LNG installations with a total storage capacity of between 5 t and 200 t. The installation is limited from the gas inlet or loading LNG area to the gas outlet or unloading LNG area. Filling systems are not covered.

EN 1626:2008 – Cryogenic vessels – Valves for cryogenic vessels

ISO 28460:2010 – Installation and equipment for LNG Ship-to-shore interface and port operations
This standard specifies the requirements for ship, terminal and port service providers to ensure the safe transit of an LNG carrier (LNGC) through the port area and the safe and efficient transfer of its cargo.

Other ISO Standards affecting LNG industry currently under preparation:

ISO/DTS 16901: Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface

ISO/DIS 16903: Characteristics of LNG influencing design and material selection

ISO/DIS 16904: Design and testing of LNG marine transfer arms for conventional onshore terminals

ISO/DTR 17177: Unconventional LNG transfer systems

ISO/AWI TR 18624. Guidance for conception, design and testing of LNG storage tanks

ISO/DTS 18683: Guidelines for systems and installations for supply of LNG as fuel to ships

ISO/NP 20088: Determination of the resistance to cryogenic spillage of insulation materials (at proposal stage)

International Risk and Safety related standards and guidelines

EN 1160:1996 - Properties and materials for LNG (being revised as an ISO - CD 16903)
This International Standard gives guidance on the characteristics of liquefied natural gas (LNG) and the cryogenic materials used in the LNG industry. It also gives guidance on health and safety matters and is intended as a reference for use by persons who design or operate LNG facilities.

Seveso III Directive EU Directive 2012/18/EU
The Seveso Directive deals with the control of onshore major accident hazards involving dangerous substances and entered into force in August 2012 and will be fully applicable in June 2015.

USCG - Guidance Related to Waterfront LNG Facilities

This circular provides guidance to an applicant seeking a permit to build and operate a shore side LNG terminal. It looks at the timing and scope of the process that is necessary to ensure full consideration is given to the safety and security of the port, the facility and the vessels transporting the LNG.

Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents - API Recommended Practice 2003, 7th Edition
Presents the current state of knowledge and technology in the fields of static electricity, lightning, and stray currents applicable to the prevention of hydrocarbon ignition in the petroleum industry and is based on both scientific research and practical experience. The principles discussed are applicable to other operations where ignitable liquids and gases are handled.

Energy Institute Model Code of Safe Practice Part 15: Area Classification Code for Installations Handling Flammable Fluids (formerly referred to as IP 15)
EI 15 provides methodologies for hazardous area classification around equipment that stores or handles flammable fluids in the production, processing, distribution and retail sectors. It is a sector specific approach to achieving the hazardous area classification requirements for flammable fluids required in the UK by the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002.

EU ATEX Directives
ATEX is the name commonly given to the two European Directives for controlling explosive atmospheres:
1) Directive 99/92/EC 'ATEX 137' is on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.
2) Directive 94/9/EC 'ATEX 95' is on the approximation of the laws of Members States concerning equipment and protective systems intended for use in potentially explosive atmospheres.

LNG Fire Protection and Emergency Response, 2007 Edition IChem E
This booklet was written to improve understanding of the nature and hazards of LNG and the special fire hazards management and emergency response measures required for such facilities.

IMO Revised Recommendations on the Safe Transport of Dangerous Cargoes and Related Activities in Port Areas
These Recommendations set out a framework within which legal requirements can be prepared by Governments, whether for the first time or as a revision, to ensure the safe transport and handling of dangerous cargoes in port areas. There commendations do not specify standards of construction and equipment.

International standards on Training of personnel[5]

STCW Convention – IMO
The Convention prescribes minimum standards relating to training, certification and watchkeeping for seafarers which countries are obliged to meet or exceed.

LNG Shipping Suggested Competency Standards – SIGTTO
This document has been prepared for the guidance of ship owners and operators who may be entering LNG ship operation for the first time. It highlights the statutory requirements for training LNG carrier crews and the provisions of STCW, as it applies to gas carriers.

Competence Related to the On Board Use of LNG as Fuel – DNV
The standard identifies a suggested minimum level of knowledge and skills for people in various roles on board a vessel using LNG as fuel.

[5] References are made exclusively to personnel onboard ships carrying or using LNG.

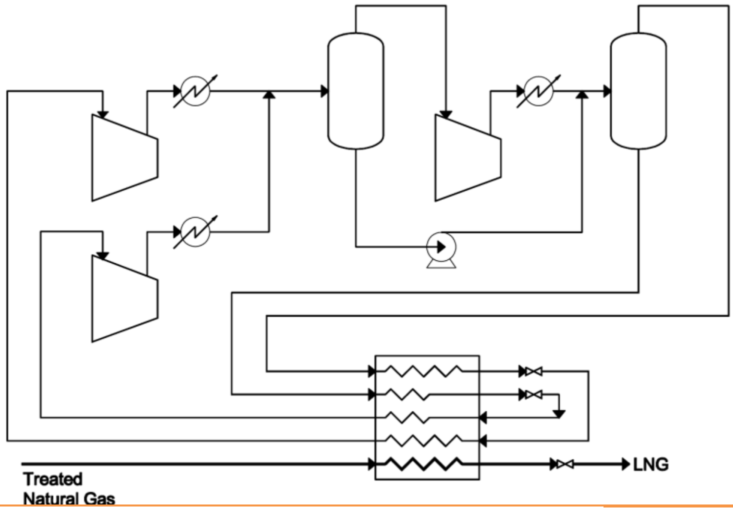
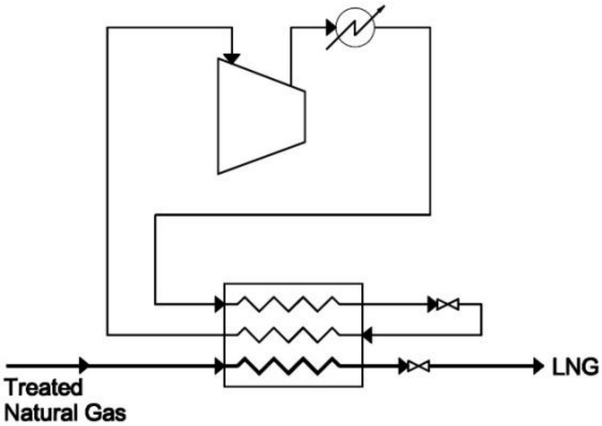
Appendix E. Small Scale LNG parties

Below in the table, the different parties involved in Small Scale LNG are shown and some examples of parties involved are also given.

LNG Player Role	LNG Value Chain: Across value chain	Gas Supply	Liquefaction	Transport: Road	Transport: Ship	Storage &Terminals, Break Bulk	Regasification
Gas Owners, Capacity Owners	EWC, PetroChina, China Natural Gas Co. Ltd., Shell	Pacific Rubiales, SinoPac, PetroChina, CNOOC	CNOOC, PetroChina, Skangass, Pacific Rubiales, CNOOC, Gasnor AS (Shell)		Gasnor AS (Shell), Linde (AGA),	Eneco. Gasnor AS (Shell)	Enagas, Pacific Rubiales, PGN
Asset Owners/ Operators	Shell, PetroChina	Pacific Rubiales, EWC	Petrobras, Shell (Gasnor AS), Lyse (Skangass), Exmar, EWC, Guanghui, Linde, Prometheus	IOCL, Enagas, Shell (Gasnor AS), Skangass, Guanghui, Linde (AGA)	MISC, Jaccar Holdings, Anthony Veder, Norgas, I.M. Skaugen, Sirius	Gate, Fluxys, Gothenburg, Vopak, Skangass, Gasunie, Guanghui, Linde, IOCL	Saibu Gas, Gasnor AS (Shell), Lyse (Skangass), Exmar, Engages.
Technical Integrators (contractors)			China Petroleum Eng., CIMC, Salof, Linde, Black & Veath, Wison, HQCEC	Chart-Ferox, Cryolor, Indox, Cazgir,		Fluor, Linde (Cryo AB, Cryostar), Chart-Ferox, Aritas, CIMC	Linde, Chart-Ferox
Technology Providers			APCI, B&V, Linde, Salof, Chart, GE, Hamworthy, HQCEC, Chengdu Cryogenics, Sichuan Air, Nordon, Shell	West-port	Knutsen, Exmar, Teekay, TGE Marine, Wärtsila	Chart, Linde (Cryo), TGE Gas Eng.	Linde
Government, Regulators	EU (DG-Energy), National bodies, NDRC (PRC)		FERC, BPMigas , Port Authorities, SKKMigas	ADR (europe)	SIGTTO, GIGNL, IMO	OFGEM (UK), ANP (Brasil), FERC, Port Authorities	

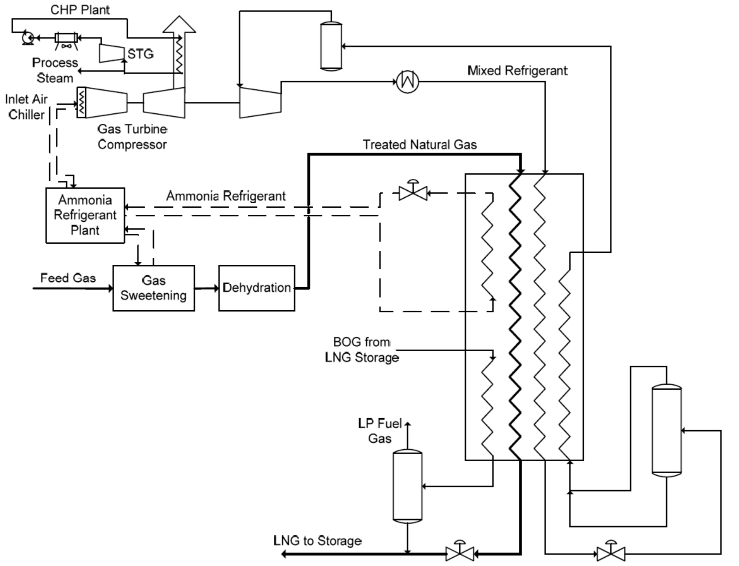
Appendix F. Liquefaction processes

In the below table an overview of the liquefaction processes is given that are proposed by various technology providers for SSLNG, but not yet commercially applied in several projects.

Technology	Simplified Process Scheme
KSMR (Korea SMR) **Company: KOGAS** **Refrigerant: MR** **MCHE: PFHE**	
Single MR **Company: Chart (Open Art)** **Refrigerant: MR** **MCHE: PFHE**	

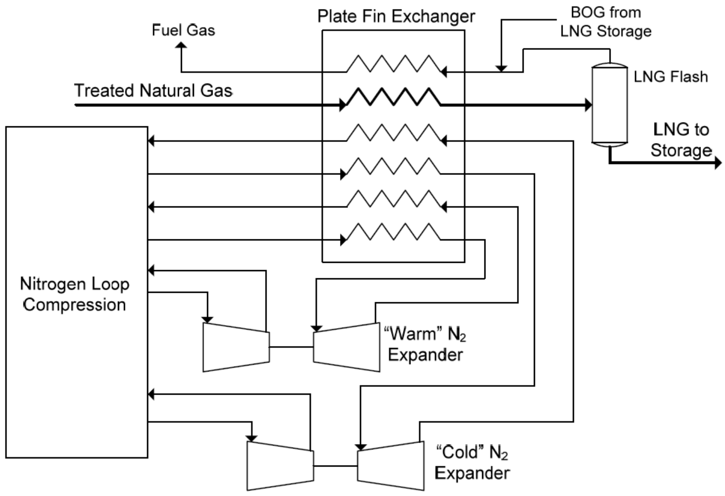
OSMR
(Optimized Single Mixed Refrigerant)

Company: LNG Limited
Refrigerant:
Precooler: NH3
Liquefier: MR
MCHE: PFHE



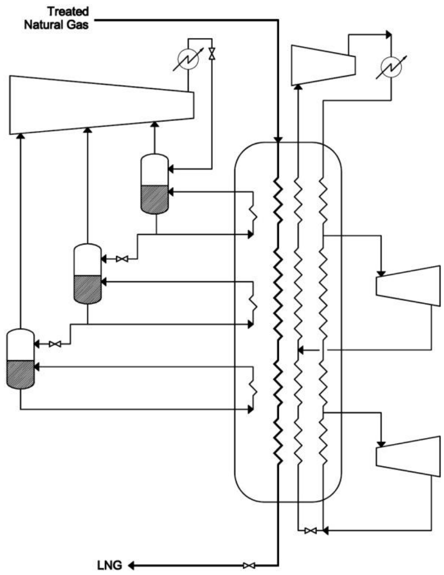
NDX-1

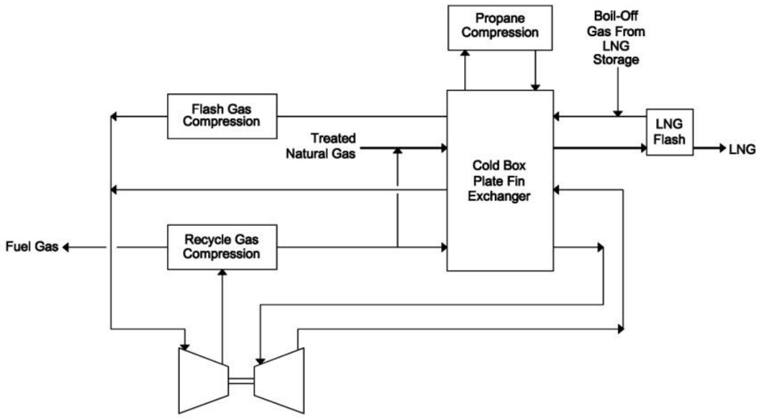
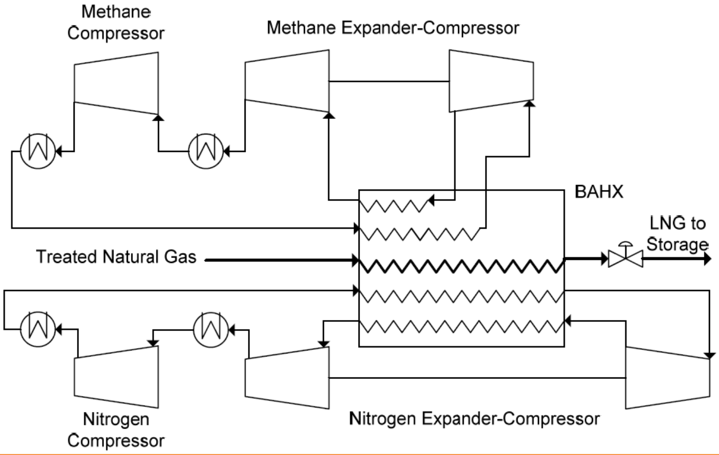
Company: Mustang
Refrigerant: N2
MCHE: PFHE



C3 Precooling N2 Expander

Company: APCI
Refrigerant:
Precooler: C3
Liquefier: N2
MCHE: SWHE



OCX-R **Company: Mustang** **Refrigerant:** **Precooler: C3** **Liquefier: MR (Part of Inlet Feed Gas)** **MCHE: PFHE**	
Niche LNG **Company: CB&I Lummus** **Refrigerant:** **Precooler: C1** **Liquefier: N2** **MCHE: PFHE** **Efficiency: Normal** **Simplicity: Normal** **Reference: Non**	

Appendix G. Small Scale LNG fleet, current and orderbook

Current Fleet

Source (Clarksons, 2014) "Clarkson Research". This data is subject to Clarksons' Terms and Conditions of Use" and cannot be used without permission.

Type	Name	Size M^3	Flag	Built	Current Owner
L.N.G.	Pioneer Knutsen	1,100	Norway	2004	Knutsen OAS Shipping
L.N.G.	North Pioneer	2,512	Japan	2005	Japan Liquid Gas
L.N.G.	Shinju Maru No. 1	2,513	Japan	2003	NS United K.K.
L.N.G.	Kakurei Maru	2,536.00	Japan	2008	Tsurumi Sunmarine
L.N.G.	Shinju Maru No. 2	2,536.00	Japan	2008	NS United K.K.
L.N.G.	Kakuyu Maru	2,538.00	Japan	2013	Tsurumi Sunmarine
L.N.G.	Akebono Maru	3,556.00	Japan	2011	NS United K.K.
L.N.G.	Coral Energy	15,600.00	Netherlands	2012	Anthony Veder
L.N.G.	Aman Hakata	18,800.00	Malaysia	1998	MISC
L.N.G.	Aman Bintulu	18,928.00	Malaysia	1993	MISC
L.N.G.	Aman Sendai	18,928.00	Malaysia	1997	MISC
L.N.G.	Sun Arrows	19,100.00	Bahamas	2007	Mitsui O.S.K. Lines
L.N.G.	Surya Aki	19,474.00	Bahamas	1996	P.T. Humpuss
L.N.G.	Surya Satsuma	23,096.00	Japan	2000	Mitsui O.S.K. Lines
LNG Bunkering	Seagas	170	Sweden	1974	Aga Gas AB
LNG/Eth/LPG	Kayoh Maru	1,517.00	Japan	1988	Daiichi Tanker Co.
LNG/Eth/LPG	Coral Anthelia	6,500.00	Netherlands	2013	Anthony Veder
LNG/Eth/LPG	Coral Methane	7,500.00	Netherlands	2009	Anthony Veder
LNG/Eth/LPG	Norgas Creation	10,030.00	Singapore	2010	I.M. Skaugen
LNG/Eth/LPG	Norgas Innovation	10,030.00	Singapore	2010	I.M. Skaugen
LNG/Eth/LPG	Norgas Conception	10,030.00	Singapore	2011	I.M. Skaugen
LNG/Eth/LPG	Norgas Invention	10,030.00	Singapore	2011	I.M. Skaugen
LNG/Eth/LPG	Norgas Unikum	12,000.00	Singapore	2011	Teekay Corporation
LNG/Eth/LPG	Bahrain Vision	12,022.00	Singapore	2011	Teekay Corporation

Orderbook

Source "Clarkson Research". This data is subject to Clarksons' Terms and Conditions of Use" and cannot be used without permission.

Status	Type	Size M^3	Flag	Built	Yard	Current Owner
On Order	C.N.G.	2,200.00	2016-05	2016-05	Hantong S.Y.	PLN Persero
On Order	L.N.G.	14,000.00	2015-08	2015-08	Fengshun Ship Hvy	Zhejiang Huaxiang
On Order	L.N.G.	28,000.00	2015-03	2015-03	COSCO Dalian	Dalian Inteh Group
On Order	L.N.G.	30,000.00	2015-01	2015-01	Jiangnan SY Group	CNOOC
On Order	L.N.G.	30,000.00	2015-03	2015-03	Xinle S.B.	CNPC
On Order	LNG Bunkering	5,100.00	2016-	2016-	Hanjin H.I.	Nippon Yusen Kaisha
On Order	LNG/Eth/LPG	27,500.00	2016-	2016-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2016-	2016-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2016-	2016-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2016-	2016-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2015-	2015-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2015-	2015-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2015-	2015-	Sinopacific Offshore	Jaccar Holdings
On Order	LNG/Eth/LPG	27,500.00	2015-	2015-	Sinopacific Offshore	Jaccar Holdings

Appendix H. Examples of Modified Terminals

Traditionally, import terminals were built to regasify LNG, but that has changed today. Some of the terminals are being modified to be able to break-bulk, re-load or bunker ships and trucks. Below in the table an overview of such terminals in Europe.

Country	Terminal	Vessel reloading	Truck loading
Belgium	Zeebrugge	✓	✓
France	Fos Max Fos Tonkin Montoir	✓ ✗ ✓	✗ ✓ ✓
Netherlands	Gate	✓	✓
Portugal	Sinès	✓	✓
Spain	Cartagena, Barcelona, Huelva, Mugardos	✓	✓
	Bilbao, Sagunto, Gijon	✗	✓

Appendix I. Examples of Small Scale Terminals, Operating and Planned

Continent	Country	Mode	Start-up	ktpa	Storage (m³)	Site /Company Name	Location
Asia	Japan	In operation	1997	160	80.000	Shin-Minato Works/ Gas Bureau, City of Sendai	Sendai
Asia	Japan	Under construction	2015	-	10.000	Kushiro LNG terminal/JX Nippon Oil & Energy	Kushiro
Asia	Japan	Under construction	2015	-	12.000	Akita LNG Terminal/Tobu Gas	Akita
Asia	Japan	In operation	2003		10.000	Takamatsu/Shikoku-Gas	Takamatsu
Asia	Japan	In operation	1996		86.000	Kagoshima/ Nippon Gas	Kagoshima
Asia	Japan	In operation	2003		35.000	Nagasaki Works	Nagasaki
Europe	Turkey	In operation	2015		20.000		Åbo/Turku
Europe	Sweden	In operation			6.500	Nordic LNG	Øra LNG, Fredriksta d
Europe	Norway	In operation			500	Hafslund	Oslo
Europe	Norway	In operation			850	Skagerak Naturgass	Porsgrunn
Europe	Norway	In operation			1.250	Gasnor	Lista
Europe	Norway	In operation			1.000	Gasnor	Halhjem
Europe	Norway	In operation			500	Gasnor	Ågotnes CBB
Europe	Norway	In operation			500	Saga Fjordbase	Florø
Europe	Norway	In operation	2003		1.500	Naturgass Møre	Sunndalsø ra
Europe	Norway	In operation	2010		1.000	Naturgass Møre	Ålesund
Europe	Norway	In operation			3.500	Gasnor	Mosjøen
Europe		In operation	2011		20.000	AGA	Nynäsham n terminal
Europe	Finland	In operation	2014		30.000	Skangass, Preem	Lysekil
Europe	Sweden	In operation	2015		20.000	Swedegas/vopak	Göteborg
Asia	Japan	In operation	2003		35.000	Nagasaki Works	Nagasaki

Appendix J. Examples of Small Scale Liquefiers, Operating and Planned

In this Appendix, an overview of the SSLNG plants from 0.05 – 1.0 mtpa (= 50ktpa -1000ktpa)is given per region.

Continent	Country	Mode	ktpa	Site/Company Name	Location
Africa	Algeria	In operation	1000	Skikda - GL1K (T1-4)	Algeria
America	USA	in operation	64	Williams, Carlstadt, NJ, Peakshaver	Carlstadt, NJ
America	Canada	in operation	68	Gaz Metropolitain Montreal, Quebec, LNG Peak Shaver	Canada
America	USA	in operation	114	Philadelphia Gas Works, Philadelphia, PA, Peakshaver	Montreal, Quebec,
America	USA	in operation	60	AGL Chattanooga, TN Peakshaver	Chattanooga
America	USA	in operation	59	NiSource, Ludlow, MA, Peakshaver	Ludlow
America	USA	in operation	73	NiSource, La Porte, IN, Peakshaver	La Porte
America	USA	in operation	140	Hopkinton LNG Corp	Hopkinton
America	USA	in operation	52	Citizens Energy Group, Indianapolis, IN, Peak Shaver	Indianapolis, IN,
America	USA	in operation	60	Pickens Plant	USA
America	USA	in operation	110	Cove Point LNG	Cove Point
America	USA	in operation	133	Clean Energy Fuels Boron, California Plant	Boron, California
America	Colombia	in construction	500	Pacific Rubiales (Exmar ops)	Puerto Bahía (Colombia's North coast)
America	Caribean	planned	500	Guadeloupe/Martinique LNG 50% EDF & 50% Gasfin	Guadeloupe/ Martinique
America	Canada	Planned	900	BC LNG T1	
America	USA	Planned	1000	Elba Island LNG T2	
America	Equador	in operation	73	Machala LNG	
Asia	China	in operation	318	Guanghui Energy	Turpan, Xinjiang
Asia	China	in operation	318	Guanghui Energy	Kumul, Xinjiang
Asia	China	in operation	318	Guanghui Energy	Altay, Xinjiang
Asia	China	in operation	424	Shaanxi Zhongyuan Green Energy	Korla, Xinjiang
Asia	China	in operation	106	Xinjiang Hongkong Gas	Korla, Xinjiang
Asia	China	in operation	53	Xinjiang Xinjie	Hotan, Xinjiang
Asia	China	in operation	64	Xinjiang Borui Energy	Bayingol, Xinjiang

Asia	China	in operation	106	Xinjiang Xinjie	Karamay, Xinjiang
Asia	China	in operation	212	Shaanxi Zhongyuan Green Energy	Yulin, Shaanxi
Asia	China	in operation	212	Yuanheng Energy	Yulin, Shaanxi
Asia	China	in operation	106	Xi'an City Xilan Natural Gas Group	Yulin, Shaanxi
Asia	China	in operation	212	Shaanxi Lvyuan Natural Gas Group	Yulin, Shaanxi
Asia	China	in operation	212	Huanghe Mining	Weinan, Shaanxi
Asia	China	in operation	95	China Natural Gas investment	Xi'ning, Qinghai
Asia	China	in operation	212	Shaanxi Zhongyuan Green Energy	Yanchi, Ningxia
Asia	China	in operation	64	Kunlun Energy	Lanzhou, Gansu
Asia	China	in operation	551	Kunlun Energy	Tai'an, Shandong
Asia	China	in operation	64	Hubei Huashang Environmental Protection technology	Wuhan, Hubei
Asia	China	in operation	64	Shenzhen Gas	Xuancheng, Anhui
Asia	China	in operation	127	Ningxia Clean Energy Development	Yinchuan, Ningxia
Asia	China	in operation	212	Dazhou Huixin Energy	Dazhou, Sichuan
Asia	China	in operation	64	Cangzhui Datong Natural Gas	Dazhou, Sichuan
Asia	China	in operation	127	Yunnan Jiehua Clean Energy Development	Kunming, Yunnan
Asia	China	in operation	64	Binhai New Energy	Dagang, Tianjin
Asia	China	in operation	138	Shanxi Yigao	Jincheng, Shanxi
Asia	China	in operation	106	China Leason	Jincheng, Shanxi
Asia	China	in operation	64	Shanxi Jincheng Tianyu New Energy	Jincheng, Shanxi
Asia	China	in operation	64	Shanxi Natural Gas	Pingyao, Shanxi
Asia	China	in operation	64	Inner Mongolia ECQ Natural Gas	Ordos, Mongolia
Asia	China	in operation	127	Ordos Xinsheng NG development	Ordos, Mongolia
Asia	China	in operation	212	China National Coal Group	Ordos, Mongolia
Asia	China	in operation	85	Inner Mongolia Hengkun Chemical	Ordos, Mongolia
Asia	China	in operation	64	Xinxingsheng Energy	Bactou, Mongolia
Asia	China	in operation	64	Bactou, Xinyan Natural Gas	Ordos,

					Mongolia
Asia	China	in operation	64	Bactou Huanda New Energy	Ordos, Mongolia
Asia	China	in operation	106	Bactou Huanda New Energy	Ordos, Mongolia
Asia	China	in operation	212	PetroChina	Wuhau, Mongolia
Asia	China	in operation	212	China State Reserve Energy & Chemical	Zhangijakou, Hebei
Asia	China	in operation	212	Hebei Huaqi Natural Gas	Langfang, Hebei
Asia	China	in operation	74	Huagang Gas	Canhzhou, Hebei
Asia	China	planned	254	Inner Mongolia Huineng Coal Chemical Co., Ltd.	Beiniuchuan (Erdos)
Asia	China	planned	290	Sichuan Tongkai Energy and Techn. Devel. Co.	
Asia	China	planned	407	Jincheng Huagang Natural Gas Co. Ltd.	Jincheng
Asia	China	planned	424	Shaanxi Gas Group Co., Ltd	Yangling
Asia	China	in operation	321	Xinjiang Guanghui LNG Development Co. Ltd.	Shan Shan
Asia	China	in operation	295	Xinjiang Guanghui LNG Development Co. Ltd.	Jimunai
Asia	China	in operation	318	Ningxia Hanas NG Co. Ltd.	Yinchuan
Asia	China	in operation	212	Xingxing Energy	Erdos
Asia	China	in operation	127	CNOOC	Zhuhai
Asia	China	in operation	212	Sichuan Dazhou Huixin Energy Co., Ltd.	Dazhou
Asia	China	in operation	212	China Natural Gas Co. Ltd.	Guangan
Asia	China	in operation	212	China Natural Gas Wuhai Co. Ltd.	Guangyuan
Asia	China	in operation	382	Xinjiang Guanghui New Energy Co., Ltd.	Hami
Asia	China	in operation	318	Shaanxi Yanchang Petroleum(Group) Co. Ltd.	Yanchang
Asia	China	in operation	422	China Natural Gas Corp. Ltd.	Ansai
Asia	Japan	in operation	123	Japex - Yufutsu Liquefaction Plant	Hokkaido
Asia	Indonesia	Under Construction	500	Sengkang LNG T1	
Asia	Indonesia	Under Construction	500	Sengkang LNG T2	
Asia	Indonesia	Planned	500	Sengkang LNG T3	
Asia	Indonesia	Planned	500	Sengkang LNG T4	
Australia	Australia	in operation	60	Energy Develop. Ltd	Karratha
Australia	Australia	in operation	51	Wesfarmers LPG Ltd.	Kwinana
Australia	Australia	in operation	54	Cryocenter, Linde	Dandenong
Australia	Australia	Planned	1000	Abbot Point LNG T1	

Australia	Australia	Planned	1000	Abbot Point LNG T2	
Australia	Australia	Planned	1000	Beach Energy-Itochu LNG T1	
Australia	Australia	Planned	1000	Sun LNG	
Europe	Norway	in operation	80	Kollsnes LNG II	Kollsnes
Europe	Norway	in operation	300	Risavika (Stavanger) LNG plant	Stavanger
Europe	Russia	planned	300	Vysotsk	Vysotsk
Europe	Russia	planned	150	Kalingrad-2	Kalingrad
Europe	Russia	planned	147	Prionezhskyi reg	
Europe	Russia	planned	84	Ust-Kut - Gazprom	Ust-Kut
Europe	Russia	planned	56	Tyuljachi	
Europe	Russia	planned	56	Volzhskoye	
America	Canada	Planned	900	BC LNG T2	