

RETAIL LNG HANDBOOK

Retail LNG & The Role of LNG Import Terminals



Report by the GIIGNL Technical Study Group
on the possible role of LNG import terminals
within the emerging Retail LNG Market.

1st Edition: 2015



This first (2015) edition of the GIIGNL Retail LNG Handbook reflects GIIGNL's understanding of the Retail LNG market and best current practice at the time of publication. Information is provided in summary form only and is intended to provide a broad understanding and knowledge of the Retail LNG market.

The terms Retail LNG, Mobile LNG, Small Scale LNG and other descriptive terms have been used to describe, either the miniaturization of a traditional LNG value chain, or the consumption of LNG by small end user applications. For the purposes of this Handbook, GIIGNL utilizes the term "Retail" to cover the broad scope of LNG activities at scale far less than the traditional LNG value chain.

This handbook is not intended to provide the reader with detailed operational procedures, as such, but sets out the practical issues and requirements to guide and facilitate a skilled operator team to work out suitable operational procedures for Retail LNG applications.

Please always consult the GIIGNL website www.giignl.org to check for the latest version of this handbook, especially when referring to a pdf download or a printout of this handbook.

Content Disclaimer

The purpose of this handbook is to serve as a reference manual to assist readers to understand the current and future Retail LNG market, LNG supply to this market, safety and operational aspects, applicable codes and standards, and equipment available to be used by the members of the "Groupe International des Importateurs de Gaz Naturel Liquéfié" (GIIGNL). It is neither a standard nor a specification and should be viewed only as a summary of observations within the industry.

Although this Retail LNG Handbook may contain much useful information, it is not specifically intended to work out procedures for LNG transfer, storage or distribution to end users. No proprietary procedure, nor particular manufacture of equipment, is recommended or implied suitable for any specific purpose in this handbook. Readers should ensure that they are in possession of the latest information, standards and specifications for any procedures and equipment they intend to employ.

Although GIIGNL used reasonable care to include in this Handbook information which it believes is up-to-date and accurate, GIIGNL makes no representations or warranty as to the adequacy, accuracy, completeness or correctness of such information nor does it warrant or represent that such information shall be complete in every respect. GIIGNL, and any of its members, disclaim any direct or indirect liability as to information contained in this document for any industrial, commercial or other use whatsoever.

The natural gas and liquefied natural gas (LNG) industries are changing. The influx of supply, low prices, and environmental benefits of natural gas are driving consumers to convert from other fossil fuels. Natural gas consumers on pipeline systems have the ability to benefit, but for those not connected, LNG may be the only opportunity to convert to natural gas. As this market evolves, a unique opportunity may emerge for some existing participants in the LNG market and could lead to a shift in business focus, potentially adding to or even transforming the traditional role of LNG Import Terminals.

As surmised by the GIIGNL's Technical Study Group (TSG) at the outset of their endeavor, virtually every member company had historical experience with, was in the midst of expanding its services to include, or was actively engaged in the study of, Retail LNG. The market drivers, value propositions, trends and future prospects for Retail LNG that have widely been publicized were generally confirmed although in an overall more conservative outlook.

As a representative body of experienced, long term LNG Import Terminal operators, GIIGNL was uniquely qualified to stress in its Handbook the importance of managing the inherent risk associated with LNG, the application of suitable

codes and standards and the use of proper equipment. The study of the aspects of LNG supply and use including safety, security, staffing, equipment siting, and operations is hoped to provide an illustrative framework form which the industry can jointly move towards best practices.

While Retail LNG is considered by many to be "new" there is substantial historical experience with all aspects of the market. LNG Import Terminals, including the experience and competence of their staffing, can play a key role in not only the incubation and growth of the Retail market, but the molding and shaping of regulatory framework, applicable codes and standards and operational best practices. GIIGNL's Retail LNG Handbook has been produced to serve as a starting point, guide and reference for the participants of this emerging market.

With regard to the Retail LNG market, the following representative examples of themes observed by GIIGNL's TSG are provided:

- ✓ **Properties and hazards of LNG** – The inherent risks associated with LNG that has been observed and carefully mitigated for close to five decades exist in the Retail LNG market. Although there are differences in

scale and scope between the markets, the lessons learned, and practices employed, by LNG Import Terminal operators provide the Retail LNG market with demonstrative guidance on what prudent operations can look like.

- ✓ **Codes and Standards** – Regional differences in the application of particular codes and standards exist. While the current operation of LNG Import Terminals is viewed as having a robust and well proven set of codes and standards, it has been recognized that the scale and scope differences that exist with Retail LNG have produced "gaps" in coverage that should be addressed with the drafting of focused codes and standards.
- ✓ **Current Market** – Retail LNG market drivers were identified and illustrative value propositions detailed. Although it was confirmed that significant opportunity exist for participants in the LNG value chain, GIIGNL's TSG has found that many proposed Retail LNG developments appear to have overstated economic benefits and significant exposure to oil pricing fluctuations.
- ✓ **Equipment** – As with other "emerging" markets, there can exist a corresponding emergence of new technologies and improvement in old technologies. While some advancement with regard to the equipment utilized in the Retail LNG value chain is being observed, much of the

improvement has been found to be in the “economies of scale” that have presented themselves due to increased utilization of proven equipment and technologies.

- ✓ **Availability of LNG Supply** – Although some challenges exist, LNG Import Terminals have been confirmed as ideal “hubs” in a distributive model of LNG supply to the Retail markets.
- ✓ **Aspects of LNG Supply** – With regard to safety, security, staffing, equipment siting, and transfer operations LNG import terminals provide excellent references for the development of the Retail LNG facilities.
- ✓ **Trends and Prospects** – The general level of interest in Retail LNG that can be observed in the press and trade publications has been observed by GIIGNL’s member companies. Although the industry “buzz” is substantial, volumes of LNG traded in the Retail Market currently and for the foreseeable future will only represent a small percentage of the global LNG trade. However, even these modest volumes will offer many opportunities for current, and new, LNG market participants to develop new business, expand their services and increase utilization of existing infrastructure.

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List of abbreviations

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AAR	Association of American Railroads
ABS	American Bureau of Shipping
APCI	Air Products
BOG	Boil Off Gas
BLEVE	Boiling Liquid Expanding Vapor Explosion
BV	Bureau Veritas
CCS	China Classification Society
CEF	Connecting Europe Facility
CFR	Code of Federal Regulations (US)
C&I	Commercial and Industrial
CLNG	Center for Liquefied Natural Gas
CO2	Carbon Dioxide
COMAH	Control of Major Accident Hazards (UK)
CSG	Commercial Study Group
DGE	Diesel Gallon Equivalent
DNV	Det Norske Veritas
DOT	United States Department of Transportation
E&P	Exploration and Production
EMD	Electro-Motive Diesel (locomotive manufacture)
EMSA	European Maritime Safety Agency
ESD	Emergency Shutdown
EU	European Union

FEMA	Federal Emergency Management Agency (US)
FID	Final Investment Decision (final company approval for projects)
FRA	Federal Railroad Administration (US)
GIE	Gas Infrastructure Europe
GIIGNL	International Group of Liquefied Natural Gas Importers
GHG	Greenhouse Gas
HAZOP	Hazard and Operability Study
HHP	High Horsepower
HPDI	High Pressure Direct Injection
IEA	International Energy Agency
IGU	International Gas Union
IMO	International Maritime Organization
ISPS	International Ship and Port Facility Security
ISO	International Standards Organization (used as reference to intermodal containers)
JGA	Japan Gas Association
JIP	Joint Industry Project
KR	Korean Register of Shipping
LDC	Local Distribution Company
LFL	Lower Flammable Limit
LNG	Liquefied Natural Gas
MGO	Marine Gas Oil
MITI	Ministry of International Trade and Industry



List of abbreviations

MR	Mixed Refrigerant (SMR = single, DMR = Dual)	TAG	Technical Advisory Group (AAR)
MTPA	Million Ton Per Annum	TEN-T	Trans-European Transport Network
NBP	National Balancing Point	TSG	Technical Study Group
NER	Natural Evaporation Rate	TTF	Title Transfer Facility
NFPA	National Fire Protection Association	VOC	Volatile Organic Compounds
NG	Natural Gas	UFL	Upper Flammable Limit
NGO	Non-Governmental Organization		
NK	Nippon Kaiji Kyokai		
NOx	Mono-nitrogen oxides		
OCIMF	Oil Companies International Marine Forum		
ODS	Ozone Depleting Substances		
OSHA	Occupational Safety and Health Administration (US)		
PERC	Powered Emergency Release Coupling		
PHMSA	US Department of Transportation Pipeline and Hazardous Materials Safety Administration		
PM	Particulate Matter		
PPE	Personal Protective Equipment		
QCDC	Quick Connect Disconnect Coupling		
RPT	Rapid Phase Transition		
SAE	Society of Automotive Engineers		
SGMF	Society for Gas as a Marine Fuel		
SIGTTO	Society of International Gas Tanker and Terminal Operators		
SOLAS	International Convention for the Safety of Life at Sea		



1. Introduction

1.1 Background

The natural gas and Liquefied Natural Gas (LNG) industries are changing. The advent of shale gas production in North America has shifted the supply and demand balance and led to a historic divergence between oil and natural gas prices. In Asia and to some extent in Europe, LNG pricing is still predominantly linked to oil. Over the last decade in Japan, the demand for LNG has increased and cargos are being diverted from other markets to meet the needs.

The influx of supply, low prices and environmental benefits of natural gas are driving consumers to convert from other fossil fuels. Natural gas consumers on pipeline systems have the ability to benefit, but for those not connected, LNG may be the only opportunity to convert to natural gas. As this market evolves, a unique opportunity may emerge for some existing participants in the LNG market and could lead to a shift in business focus, potentially adding to or even transforming the traditional role of LNG Import Terminals.

Traditionally natural gas has been used for heating, power generation and industrial process purposes. There has been limited use of

natural gas in the transportation sector, but it has been localized and minor in relation to the overall trade. With the conversion to natural gas by consumers a new market is developing which is different from both the traditional natural gas, including LNG and the oil-based transportation fuel markets. Retail LNG will have its own end users, require new infrastructure, and be subject to unique pricing and market dynamics.

The new Retail LNG market will attract new participants and encourage existing participants to expand their services into this new area. As with any new market, uncertainty and challenges will exist. The transferring of knowledge to new market participants on the properties and hazards of LNG and the existing codes and standards that have served the industry for decades will be of paramount importance. For existing LNG market participants, the ability to take lessons learned and established best practices and apply them in smaller scale applications in a manner that helps to maintain the LNG industry's long established record of safety while being commercially viable will be essential.

1.2 Organization & Resources

With more than 63 member companies operating in 21 countries, and with the main objectives to promote the development of activities related to LNG, the “Groupe International des Importateurs de Gaz Naturel Liquéfié” (GIIGNL) is ideally suited to explore the current opportunities and detail the areas in which the existing or planned LNG Import Terminals can participate in the Retail LNG market. The GIIGNL Technical Study Group (TSG) who is responsible to review, investigate and report on technical issues associated with the operation of LNG facilities worldwide has prepared this Handbook.

GIIGNL's main objectives are to promote the development of activities related to LNG: purchasing, importing, processing, transportation, handling, regasification and various uses of LNG. The GIIGNL's Technical Study Group also has the collective knowledge and experience to accurately review the activities in the Retail market and report such to its members. With that understanding, and based upon the increase in interest that Retail LNG has garnered, it is apparent that the emerging Retail market is well suited for its own dedicated review and analysis by GIIGNL's TSG. The TSG was mindful of the following overriding



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objectives during the preparation of the Handbook:

- ✓ **Leverage Existing Knowledgebase** - Identify how the existing human resources of LNG Import operating companies can be leveraged to support the development of the Retail LNG market. Best practices with regard to safety, design and operation should be identified and detailed so that the collective experience of GIIGNL members can be shared with the participants of the Retail LNG market.
- ✓ **Use of Existing Assets** - Identify how the existing assets of LNG Import Terminals, and if deemed important, existing distribution assets such as the LNG trucking fleets, could be used to support development of the Retail LNG market.
- ✓ **GIIGNL's Role** – Explore the possible role of GIIGNL and the value it can add to this emerging market. This is to include close coordination with GIIGNL's Commercial Study Group (CSG).

1.3 Scope of Work

The TSG will address Retail LNG through two distinct phases. Phase I will concentrate on the

activities associated with Retail LNG that primarily involve LNG import terminals. Phase I will provide limited consideration to the other aspects of the Retail LNG value chain outside of LNG import terminals. Phase I of GIIGNL's efforts has produced this first version (2015) of the Retail LNG Handbook. Phase II will concentrate on the downstream aspects of the Retail LNG value chain, provide greater detail and clarity as to the activities associated with the supply of LNG to the final end users and be completed with the issuing of a revised Retail LNG Handbook.

Three distinct regions (Far East, Europe and Americas) were solicited for input. Members of the TSG within the regions provided information which was compiled and evaluated by a sub-group (regional co-coordinators) of GIIGNL's Technical Study Group.

The following major topics form the basis of the scope of work assigned to the Retail LNG sub-group.

- ✓ **Properties and Hazards of LNG** – A review of the physical properties and associated risk of LNG. Focus and highlight the aspects of the Retail LNG value chain requiring attention with regard to the properties and hazards of LNG.

- ✓ **Regulatory Environment** – Identification of codes, standards and guidelines that are being used or being developed for Retail LNG facilities. Identify gaps or overlaps between those and those applicable to LNG Import Terminals and applicable good practices that should be followed.
- ✓ **Current understanding of the Retail LNG Market** – A review of activities ongoing, identification of market drivers for end user conversion to LNG as a primary fuel, and a quantification of the scale of the opportunities.
- ✓ **Retail LNG Equipment** - Details on the types of equipment used in the Retail LNG Value Chain. The specific equipment used in the production, storage, transfer, transportation and end use to be addressed.
- ✓ **Availability of LNG Supply** – Discussions on the availability of LNG supply for the Retail LNG market. Identify how supply from existing, expanded or new LNG import terminals, export terminals, dedicated small-mid size merchant liquefaction facilities and existing utility owned liquefaction facilities can be brought to market.
- ✓ **Aspects of LNG Supply** – Consideration of the main aspects of the supply of LNG to the



1. Introduction

Retail LNG market. To include, but not be limited to safety, security, staffing, equipment siting, transfer operations, regulatory issues, commercial and quality considerations.

- ✓ **Aspects of the use of Retail LNG** – While Phase I of the Retail LNG Handbook will predominantly be focused on the supply of LNG to the market, discussion as to the safety, security, staffing, equipment siting, transfer operations, regulatory issues, commercial and quality considerations during the transfer and at the end users sites will be discussed. Greater clarity and additional details on these aspects is planned to be provided in Phase II.
- ✓ **Trends in Retail LNG** - Investigation into regional, technology, operational, safety and security trends observed in the Retail LNG market.
- ✓ **Future Prospects** – Discussion on the regional, technology, operational, safety and security prospects of the Retail LNG market.

1.4 Organization

GIIGNL is a non-profit organization founded in December 1971 and has its central office located

in Paris. It is composed of 63 member companies from 21 countries (North America, Asia and Europe) and involved in the importation of LNG.

GIIGNL's main objectives are to promote the development of activities related to LNG: purchasing, importing, processing, transportation, handling, regasification and various uses of LNG. To this purpose, the Group provides an overview of the state-of-the art technology in the LNG industry and its general economic state in order to enhance facility operations, to diversify contractual techniques, to develop positions to be taken in international agencies, etc

The GIIGNL Technical Study Group (TSG) is a consortium of GIIGNL member companies who meet on a semiannual basis to review, investigate and report on technical issues associated with the operation of LNG facilities worldwide. The group is required to report on its activities back to the GIIGNL General Assembly on an annual basis. This group commissions studies and appoints working groups to report on issues and topics which are pertinent to LNG operations.

1.5 Study Timeline

The Retail LNG study and review was commissioned in March 2012 to investigate and report on the emergence of the Retail LNG Market.

In June 2012 representatives of the TSG met at GIIGNL's central office to prepare a clear and concise study proposal. In addition to the TSG, representatives from GIIGNL's CSG, from the Society of International Gas Tanker and Terminal Operators (SIGTTO), and from the research and development arm of a member's organization were present. At this meeting it was decided that a detailed project proposal based upon the meeting's discussions should be prepared. This proposal should including a table of contents, schedule and work organization.

The detailed project proposal was reviewed by the TSG during its December 2012 meeting in Vadodara, India. Approval to proceed with Phase I of the study was given and regional coordinators for Americas, Europe and Asia, volunteered.

In June 2013, during the 53rd TSG meeting, 3 additional member companies specified that they were joining the task force.

In September 2013, draft sections of the reports



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content were sent to task force participants for review and editing.

In February 2014, an additional member specified that they would be joining the task force.

Subsequent working drafts were issued in March and October of 2014. The final working draft of the Handbook was issued in March of 2015.

In March of 2015 the GIIGNL Retail LNG Handbook was selected to be presented at 2015 Gastech conference in Singapore.

This first version of the Retail LNG Handbook was issued for inclusion into the 2015 Gastech conference proceedings.



2. Properties and Hazards of LNG

The safety of LNG worldwide is the result of high industry standards, effective regulations, and an ardent industry commitment to rigorous risk management. As the Retail LNG market develops to include new participants and expanded roles for traditional participants, the industry will be challenged to maintain the same high level of care and commitment to safety. A core competency needed by the industry is a fundamental understanding of the properties of LNG.

A basic knowledge of LNG must begin with an examination of its chemical and physical properties which are fundamental to understanding how LNG will behave. The very properties which make LNG a good source of energy can also make it hazardous if not adequately contained. These properties determine how LNG behaves, affect our predictions about its behaviors, and influence how we assess and manage safety risks. Furthermore, to accurately understand and predict LNG behavior, one must clearly distinguish its properties as a liquid from its properties as a gas or vapor.

2.1 Basic Properties

LNG is natural gas which has been converted to liquid form for ease of storage or transport. LNG takes up about 1/600th of the volume of natural gas. Depending upon its exact composition, natural gas becomes a liquid at approximately -162 °C (-259 °F) at atmospheric pressure.

LNG's extremely low temperature makes it a cryogenic liquid. Generally, substances which are -100 °C (-48 °F or less) are considered cryogenic and involve special technologies for handling. To remain a liquid, LNG must be kept in containers which function like thermos bottles – they keep the cold in and the heat out. The cryogenic temperature of LNG means it will freeze any tissue (plant or animal) upon contact and can cause other materials to become brittle and lose their strength or functionality. Which is why the selection of materials used within the LNG industry is so important.

LNG is odorless, colorless, non-corrosive, and non-toxic. Natural gas in your home may have been liquefied at some point but was converted into its vapor form for your use. The reason the natural gas you use in your home has a smell is because an odorizing substance is added to natural gas before it is sent into the distribution grid. This odor enables gas leaks to be detected more easily.

Key liquid and gas properties for LNG are:

- ✓ Chemical Composition,
- ✓ Boiling Point,
- ✓ Density and Specific Gravity,
- ✓ Flammability, and
- ✓ Ignition and Flame Temperatures.

2.1.1 Chemical Composition

The chemical composition of natural gas is a function of the gas source and type of processing. It is a mixture of methane, ethane, propane and butane with small amounts of heavier hydrocarbons and some impurities, notably nitrogen and complex sulphur compounds and water, carbon dioxide and hydrogen sulphide which may exist in the feed gas but are removed before liquefaction. Methane is by far the major component, usually, though not always, over 85% by volume.

2.1.2 Boiling Point

Boiling point is one of the most significant properties because it defines when gas becomes a liquid. Generally defined as the temperature at which a liquid boils or at which it converts rapidly from a liquid to a vapor or gas at atmospheric pressure. The boiling point of LNG varies with its basic composition, but typically is



2. Properties and Hazards of LNG

-162°C (-259 °F).

Since throughout the Retail LNG value chain it is probable that LNG will be stored at pressures above atmospheric the use of a “saturation dome” is useful in illustrating the properties of the LNG at varying pressures and corresponding temperatures. A saturation dome graphically represents the relationship of pressure, temperature and specific volume.

2.1.3 Density and Specific Gravity

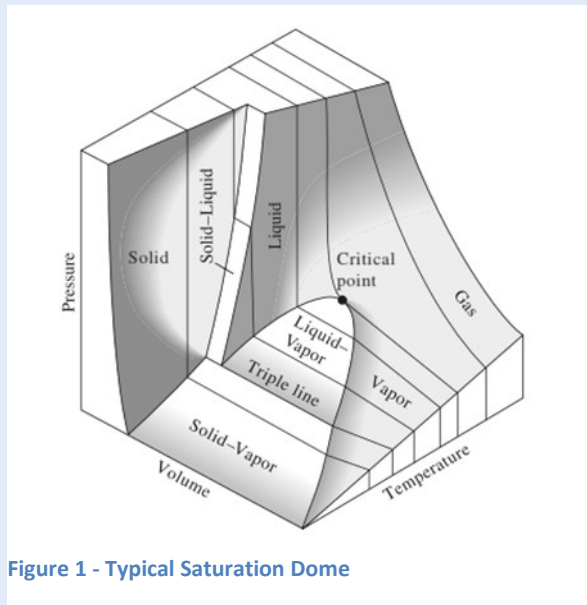


Figure 1 - Typical Saturation Dome

Density is a measurement of mass per unit of volume and is an absolute quantity. Because LNG is not a pure substance, the density of LNG varies slightly with its actual composition. The density of LNG generally falls between 420 kg/m³ and 480 kg/m³ (3.5 to 4 lb/US gal).

Specific gravity is a relative quantity. The specific gravity of a liquid is the ratio of density of that liquid to density of water. The specific gravity of a gas is the ratio of the density of that gas to the density of air. Any gas with a specific gravity of less than 1.0 is lighter than air (buoyant). When specific gravity or relative density is significantly less than air, a gas will easily disperse in open or well-ventilated areas. On the other hand, any gas with a specific gravity of greater than 1.0 is heavier than air (negatively buoyant). The specific gravity of methane at ambient temperature is 0.554, therefore it is lighter than air and buoyant.

Under ambient conditions, LNG will become a vapor. As LNG vaporizes, the cold vapors will condense the moisture in the air, often causing the formation of a white vapor cloud until the gas warms, dilutes, and disperses.

LNG vapors at the boiling point temperature (-162 °C/ -259 °F) and atmospheric pressure have

a relative density of about 1.8, which means that when initially released, the LNG vapors are heavier than air and will remain near the ground. However as methane vapors begin to rapidly warm and reach temperatures around -110 °C/-166 °F, the relative density of the natural gas will become less than 1 and the vapors become buoyant. At ambient temperatures, natural gas has a specific gravity of about 0.6, which means that natural gas vapors are much lighter than air and will rise quickly.

2.1.4 Flammability

Flammability is simply the capacity of a material to burn or ignite, causing fire or combustion. Several factors are required to start a fire from LNG vapors. In particular, the fuel and the oxygen have to be in a specific range of proportions to form a flammable mixture. This “Flammable Range” is the range of a concentration of a gas or vapor that will burn if an ignition source is introduced. The limits are commonly called the “Lower Flammable Limit” (LFL) and the “Upper Flammable Limit” (UFL). When LNG vapor mixes with air it is only flammable if within 5%-15% natural gas in air. Less than this is not enough to burn. More than

2. Properties and Hazards of LNG

this, there is too much gas in the air and not enough oxygen for it to burn.

2.1.5 Ignition and Flame Temperature

The ignition temperature, also known as auto-ignition temperature, is the lowest temperature at which a gas or vapor in air (e.g., natural gas) will ignite spontaneously without a spark or flame being present. This temperature depends on factors such as air-fuel mixture and pressure. In an air-fuel mixture of about 10% methane in air, the auto ignition temperature is approximately 540 °C (1,000 °F). Temperatures higher than the auto ignition temperature will cause ignition after a shorter exposure time to the high temperature.

The precise auto ignition temperature of natural gas varies with its composition. If the concentration of heavier hydrocarbons in LNG increases (e.g., the methane portion of the natural gas begins to evaporate or be removed from the mix), the auto ignition temperature decreases. In addition to ignition from exposure to heat, the vapors from LNG can be ignited immediately from the energy in a spark, open flame, or static electricity when they are within

the flammable limits.

The methane in LNG has a flame temperature of about 1,330 °C (2,426 °F). In comparison, gasoline has a flame temperature of about 1,027 °C (1,880 °F), which means LNG burns hotter. Also, LNG burns quickly, at a rate of about 12.5 m²/minute, compared to gasoline's burn rate of 4 m²/minute. LNG produces more heat when burning because its heat of combustion is 50.2 MJ/kg (21,600 Btu/lb), compared to that of gasoline which has a heat of combustion of 43.4 MJ/kg (18,720 Btu/lb) [1]. All the values above are provided as order of magnitude and depend of many parameters including the exact gas composition of the LNG. The combustion of LNG produces mainly carbon dioxide and water vapor.



3. The Retail LNG Process Chain

Since 1964, LNG production, export, import and distribution has followed a process sequence similar to that illustrated in Figure 2 - Simplified Traditional LNG Value Chain. The traditional LNG chain consists of several stages. It starts with exploration & production, where the natural gas is extracted from the wells. In order to facilitate its transport, it is turned into liquid phase in a liquefaction plant. LNG is then loaded on LNG tankers which then transport it to LNG receiving terminals where it is eventually regasified and sent into local pipelines for distribution to end users as vapor, or loaded for transport aboard over the road trailers in liquid form. GIIGNL has prepared a series of informational papers, which can be found on the GIIGNL website. "LNG Informational Paper No. 2 – The LNG Process Chain", addresses in detail the traditional LNG supply and distribution chain.

The development of the traditional LNG process chains is almost always very conservative in nature. Multi-year contracts for gas supply, liquefaction, shipping, terminaling (regasification) and sales to the end users were required to complete the value chain. The end users have traditionally been strong credit worthy counterparties such as gas and electric utilities who were able to pass along supply

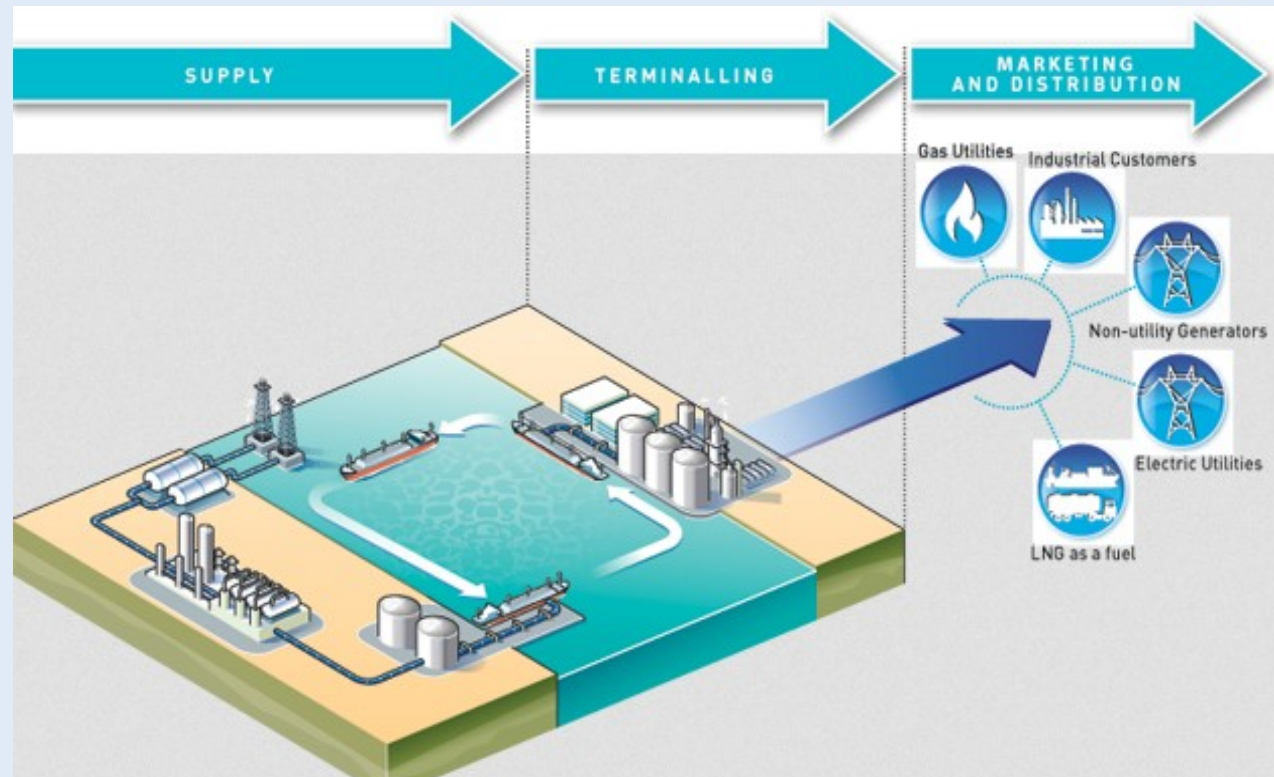


Figure 2 - Simplified Traditional LNG Value Chain (Source: GIIGNL)

chain costs to their customers through regulated tariffs. Market participants on the supply side were generally guaranteed a steady, dependable trade. "The LNG industry is based largely on a series of virtually self-contained projects made up of interlinking chains of large-scale facilities, requiring huge capital investments, bound together by complex long-term contracts, and

subject to intense oversight by host governments and international organizations at every stage of the process" [2].

The Retail LNG process chain is emerging with a very different set of market drivers. Existing LNG market participants have been forced to evaluate and adjust their strategies for addressing the Retail market. Traditional LNG

3. The Retail LNG Process Chain

market participants have begun servicing the Retail market, while facing significant competition from new market participants, many who have extensive customer focused “retail” experience with LNG and other energy products.

Even with different and unique market drivers, the Retail LNG Process Chain is similar in nature to the traditional LNG value chain. The “Hub and spoke” production and transportation

model observed in the traditional process chain with one large liquefaction facility serving dedicated or multiple LNG import terminals is being observed in the new Retail market. This Retail LNG is facilitated through one, or both, of two supply points: large-scale receipt of traditional cargoes at existing Import Terminals with break bulk capability (e.g. via trailer loading) and domestic LNG production with trailer loading.

Two main differences between the traditional process chain and the Retail chain exist:

- ✓ **Scale** and **scope** of the process chain resulting in technological and operational differences in how the LNG is handled and distributed.
- ✓ **Commercial focus** in which the “**wholesale**” nature of the traditional LNG process chain is replaced with a focus on and orientation to the **end users** of the LNG.

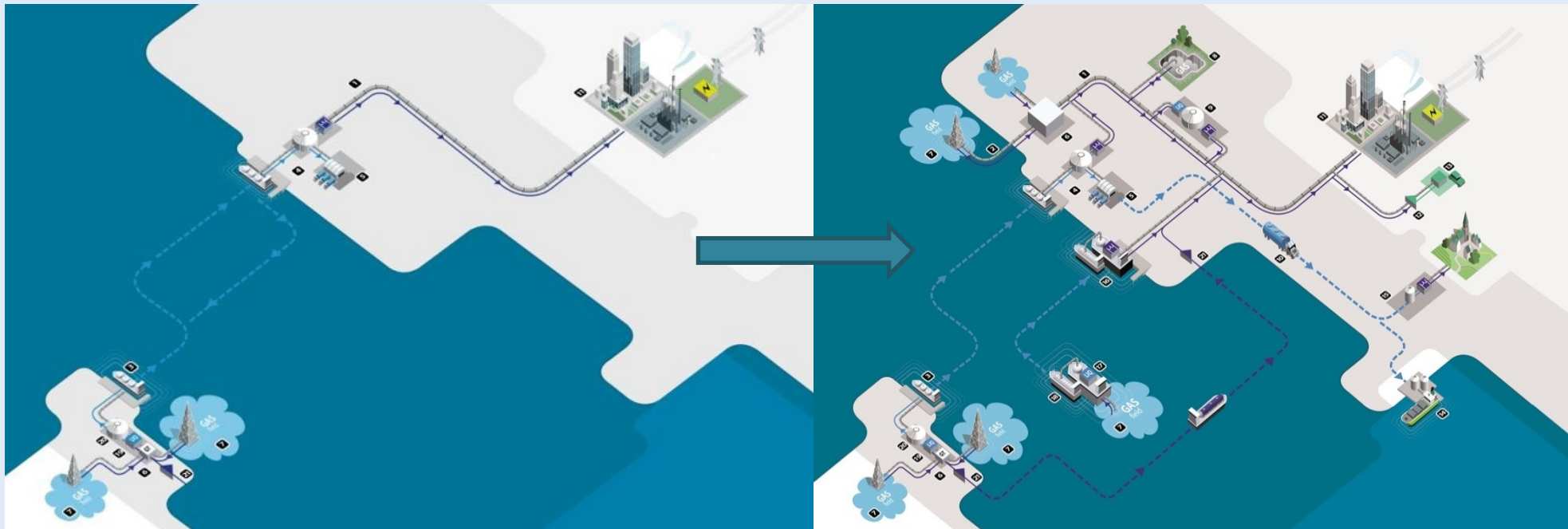


Figure 3 - Traditional and Retail LNG Process Chains (Source: ©Tractebel Engineering)

3. The Retail LNG Process Chain

These differences, and the resulting variances in the process chains, must be carefully evaluated and understood by the participants of the Retail LNG market. Lessons learned, observations and practices of the traditional LNG process chain need to be utilized where appropriate, but not without taking into account how the two process chains are materially different.



4. Codes, Standards and Industry Organizations

Industries involved in LNG trade, governments, class societies and other interested parties have worked together for many years to create codes, standards, rules and regulations that represent the collective knowledge of the participants and the current best practice within the industry. These documents can reflect the “state-of-the-art” in terms of technologies and capture the operational best practices that have been gained through actual technical design processes, operational experience, research and development and testing.

The following sections are meant to give a general overview of the codes, standards and industry organizations that may be applicable to the Retail LNG trade. Generally, the standards mentioned are not mandatory or legally binding unless brought within the law in a certain region or country. Likewise, codes are only binding where adopted into law by specific governments. However, these can be regarded as a collection of industry best practices. As the Retail LNG trade moves forward the established standards and codes can be used as starting point or as the basis for further regulatory and standardization developments.

This Handbook is intended to serve all the members of GIIGNL. As such, it takes a global

approach and identifies both the international regulations and regional specific standards.

4.1 Existing Codes/Regulations, Standards/Guidelines and Industry Organizations

The most important safety requirement for the LNG industry is to safely process, store, and transport LNG. There are a number of guidance documents and requirements which are intended to assure the safe operation of onshore and offshore LNG facilities, personnel and vessels. Strict adherence to government regulations, codes, and standards has led to the LNG industry’s exemplary safety record. Sharing best practices through non-profit trade organizations has also served to strengthen the safety culture of the entire industry.

GIIGNL members, as operators of LNG Import Terminals, have vast knowledge and understanding of these guidance documents and were involved in the drafting of many of them. In addition to GIIGNL, terminal operators belong to a number of industry organizations

committed to promoting the safe and efficient handling of LNG. As the Retail LNG market emerges, an opportunity presents itself for the current operators to assist in the development of specific guidance documents for this new market. For active LNG operators, involvement in these efforts is recommended. For government and regulatory bodies, reaching out to, consulting with, and utilizing this existing knowledge base during the formation of new codes and regulations is suggested.

The intent of regulatory authorities is to reduce the risk of adverse environmental consequences, damage to the equipment, facilities or vessels and – most importantly – human casualties. This is achieved by various means in different parts of the world. In Europe, traditionally project applicants are required to conduct a safety risk assessment according to accepted methodologies and submit the results of these studies to the permitting agencies for review. European regulations usually focus on the outcomes, rather than the specific ways to achieve the desired level of safety.

The US regulations do not prescribe formal methodologies for risk assessments. Rather, risk is evaluated by both the project applicant and regulatory authorities, using government

4. Codes, Standards and Industry Organizations

guidance to target the specific issues which risk assessments should address. Most states in the US also have regulations and permit requirements which are similar to the federal regulations. Some states have LNG-specific regulations. The state permitting and review activities are undertaken independently and tend to address local concerns. County and municipal governments also have jurisdiction in these matters, with broad discretion vested in the county fire marshal, city fire chief and town council. For marine operations, port authorities also have jurisdiction. In most cases, the various regulatory agencies and bodies issue pronouncements and regulations which are consistent and correlative, often reflected by cross-referencing between documents and/or incorporation by reference.

In Japan, the regulatory agency involved in large LNG terminal siting and operation is the Ministry of Economy, Trade and Industry (METI) which enforces the Gas Utility Industry Law, the Electricity Utility Industry Law and the High Pressure Gas Regulation Law. LNG terminal siting and operation must comply with one of these laws. For example, under the Gas Utility Industry Law, gas utility companies:

- ✓ Maintain a gas facility in accordance with an

adopted technical standard;

- ✓ Define, submit and observe their companies' own security regulations in order to ensure the safety of construction, maintenance, and operation of gas facilities;
- ✓ Assign a gas-licensed engineer to ensure the safety of construction, maintenance and operation of a gas facility.

In 2009, GIIGNL published LNG Informational Paper No. 4, Managing LNG Risk – Operational Integrity, Regulations, Codes, and Industry Organizations. This paper described the safety requirements for LNG projects, which are established by regulations, classification societies, codes, standards, and industry associations. While this paper was drafted in the early stages of the Retail LNG emergence, much of the information contained remains pertinent.

The LNG industry adheres to an international network of codes and standards which specify safe technologies, materials and designs for the construction of LNG facilities. Codes and standards enable the industry to implement generally-approved technologies and ensure a high level of safety. The development and implementation of these codes and standards promotes sharing state-of-the-art technologies and research. Some of them, mainly European

and American standards, are widely used throughout the world. Compliance with additional codes and standards may be required in specific countries.

Below is a collection of the major guidance documents and trade organizations used in the broader LNG industry as well as more recent documents more targeted to the Retail LNG market. Cumulatively, these documents help assure the operational integrity of LNG facilities and vessels and form one of the layers of protection to manage safety risks to facility workers and the public, while the organizations help to promote and share knowledge amongst active participants.

4.1.2. Codes and Regulations

In the Americas, outside of the United States, it is common for local codes and regulations to be based upon either United States or European codes or regulations. At times such codes and regulations are incorporated by reference or it is clear that they formed the basis for the local requirements. Additionally, as in other parts of the world the, countries within in the Americas at times use a mixture of codes and regulations form different origins. The following codes and regulations are commonly used in the Americas,



4. Codes, Standards and Industry Organizations

but as noted, do not reflect all codes and regulations that may be enforced.

- ✓ 49 CFR Part 193, Liquefied Natural Gas Facilities: Federal Safety Standards are applicable to import and storage facilities.
- ✓ 33 CFR Part 127, Waterfront Facilities Handling Liquefied Natural Gas and Liquefied Hazardous Gas governs the marine portion of LNG terminals.
- ✓ ASME B31.3 – Process Piping prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection and testing of piping in cryogenic plants.

In Europe, the codes and regulations specific to LNG facilities include, but are not limited to the following:

- ✓ European Union Seveso III Council Directive 2012/18/EU of 4 July 2012 - Control of Major-Accident Hazards involving Dangerous Substances. Seveso III lays down rules for the prevention of major accidents which might result from certain industrial activities and the limitation of their consequences for human health and the environment.
- ✓ EN 1160: “Installation and equipment for Liquefied Natural Gas – General characteristics of liquefied natural gas” This standard contains guidance on properties of

materials that may come in contact with LNG in the facility.

- ✓ The European code EN 1473: “Installation and equipment for LNG – Design of onshore installations” for storage capacities over 200 tonnes. EN 1473 is based on a risk assessment approach with fewer explicit prescriptive standards, compared to US regulations or US standards
- ✓ EN 1474 “Installation and equipment for LNG – Design and testing of LNG loading/unloading arms”
- ✓ EN 1532 “Installation and equipment for LNG – Ship to shore interface”
- ✓ EN 13645 (“Design of onshore installations with a storage capacity between 5 tonnes and 200 tonnes”).
- ✓ EN 14620 (“Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and -165 °C”)
- ✓ Agreement on Dangerous Goods by Road (ADR), Regulations concerning the International Transport of Dangerous Goods by Rail (RID) and International Transport of Dangerous Goods by Inland Waterway (ADN) detail requirements for the land and inland water based transportation of dangerous goods.

In the Far East, the codes and regulations specific to LNG facilities include, but are not limited to the following:

- ✓ Oil Industry Safety Directorate Standard 194 – “Storage and Handling of LNG” is an Code primarily based upon NFPA 59A which lays down minimum requirements of layout within the plant boundary for Unloading, Storage, Vaporization, Transfer & Handling and road loading facilities of LNG Terminals in India.
- ✓ The “High Pressure Gas Safety Act” regulates the production, storage, sale, import, consumption and disposal of high pressure gas in Japan. LNG distribution via overland means must also comply with this act.
- ✓ GBT 20368-2006 – Covers the production storage and handling of LNG in China

International codes and regulations addressing aspects of the Retail LNG process chain include, but are not limited to the following:

- ✓ MARPOL Annex VI, first adopted in 1997, limits the main air pollutants contained in ships exhaust gas, including sulphur oxides (SOx) and nitrous oxides (NOx), and prohibits deliberate emissions of ozone depleting substances (ODS). MARPOL Annex VI also regulates shipboard incineration, and the emissions of volatile organic compounds (VOC) from tankers [3].



4. Codes, Standards and Industry Organizations

- ✓ International Convention for the Safety of Life at Sea (SOLAS) is an international maritime treaty detailing general safety obligations of merchant ships.
- ✓ International Ship and Port Facility Security (ISPS) Code details security measures applicable to ships and port facilities.
- ✓ International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk commonly referred to as the IGC code provides an international standard for the safe carriage of LNG (and other fuels) in bulk.

4.1.3. Standards/Guidelines

- ✓ NFPA 59A: "Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)". NFPA is an international non-profit organization which specializes in fire prevention and serves as an authority on public safety practices. The NFPA 59A requirements are, for the most part, prescriptive as to the siting and design of an LNG facility.
- ✓ NFPA 52: "Vehicular Gaseous Fuel Systems Code" safeguards people and installations with requirements that mitigate the fire and explosion hazards associated with compressed natural gas (CNG) and liquefied natural gas (LNG) engine fuel systems and fueling facilities. [4]
- ✓ API Standard 620: This standard covers the design and construction of large, welded, low-pressure carbon steel above ground storage tanks (including flat-bottom tanks) that have a single vertical axis of revolution [5].
- ✓ ISO/DTS 18683: "Guidelines for systems and installations for supply of LNG as fuel to ships" gives guidance on the minimum requirements for the design and operation of LNG bunkering facilities, including the interface between the LNG supply facilities and receiving ship. It also provides requirements and recommendations for operator and crew competency training, for the roles and responsibilities of the ship crew and bunkering personnel during LNG bunkering operations, and the functional requirements for equipment necessary to ensure safe LNG bunkering operations of LNG fuelled ships. [8]
- ✓ ISO 16903:2015 "Petroleum and natural gas industries - Characteristics of LNG, influencing the design, and material selection 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. It is intended to act as a reference document for the implementation of other standards in the liquefied natural gas field. It is intended as a reference for use by persons who design or operate LNG facilities. [6]
- ✓ ISO/TR 17177:2015 "Petroleum and natural gas industries - Guidelines for the marine interfaces of hybrid LNG terminals." provides guidance for installations, equipment and operation at the ship to terminal and ship to ship interface for hybrid floating and fixed LNG terminals that might not comply with the description of "Conventional LNG Terminal" included in ISO 28460. [7]
- ✓ ISO/TS 16901:2015 "Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface." provides a common approach and guidance to those undertaking assessment of the major safety hazards as part of the planning, design, and operation of LNG facilities onshore and at shoreline using risk-based methods and standards, to enable a safe design and operation of LNG facilities [8].
- ✓ Dutch PGS 33 Part 1 and Part 2 guidelines for LNG refueling stations and LNG bunkering.
- ✓ Japan Gas Association (JGA) JGA-102 Recommended Practice for LNG Facilities
- ✓ JGA-103 Recommended Practice for Safety and Security in Gas Production Facilities.



4. Codes, Standards and Industry Organizations

- ✓ JGA-107-RPIS – Recommended Practice for LNG in-ground Storage.
- ✓ JGA-108-109 – Recommended Practice for LNG Aboveground Storage.
- ✓ SAE J26545: “Liquefied Natural Gas (LNG) Vehicle Metering and Dispensing Systems.”
- ✓ SIGTTO “Liquefied Gas Handling Principles on Ships and in Terminals” provides direction on cargo handling operations.
- ✓ SIGTTO “Guideline ship to ship transfer for LNG ships” offers guidance on ship to ship transfers of LNG.
- ✓ NB/T 1001-2011 – “Technical Specification for Vehicle Filling Station of LNG” (China)

4.1.4. Industry Organizations

- ✓ GIIGNL – provides its members with overviews of the general economic condition of the LNG industry and the most current state-of-the art LNG technology. This information enhances facility operations, strengthens the breadth and depth of contractual techniques, and supports industry positions with international agencies. GIIGNL members share information about commercial and technical developments in LNG, including safety incidents at member facilities. Activities of shared interest to GIIGNL members include

the handling, importing, processing, purchasing, regasification, transportation and uses of LNG around the world.

One important example of proprietary information, shared only among industry members, is GIIGNL’s LNG Incident Identification Study. This study began in 1992 and has been updated three times. To promote information-sharing among the industry, data is analyzed without company names. The main aims of the study are to:

- ✗ Identify actual incidents of LNG or vapor release for possible inclusion in the hazard analysis of new, modified or existing facilities.
- ✗ Advise on the severity of the identified LNG incidents to assist in evaluation of their importance and potential consequences.
- ✗ Provide information on the circumstances under which the identified LNG incidents have occurred (and their frequency where possible) to assist in the evaluation of their relevance to the particular LNG facility under review.

In order to be as comprehensive as possible, the incident study aims to include all

incidents known in the LNG Industry with the potential to cause damage to equipment or injury to personnel. GIIGNL members share this information to improve operational safety within the industry.

- ✓ SIGTTO - Founded in 1978, SIGTTO is a non-profit international society composed of more than one hundred members representing liquefied gas (LPG, LNG and others) tankers or liquefied gas marine loading or receiving terminals, or the operators of such tankers or terminals. While GIIGNL is concerned with import terminals, SIGTTO’s focus is on shipping and its interface with marine terminal operations. The purpose of the organization is to specify and promote high standards and best practices, and in so doing to maintain confidence in the level of safety achieved by the LNG industry.

This Society is an international body established for the exchange of technical information and experience, between members of the industry, to enhance the safety and operational reliability of gas tankers and terminals. To that end, the Society publishes studies and produces information papers and works of reference for the guidance of industry members.

4. Codes, Standards and Industry Organizations

SIGTTO maintains working relationships with other industry bodies, governmental and intergovernmental agencies, including the IMO, to better promote the safety and integrity of gas transportation and storage schemes. For more than thirty-five years, the Society has produced a steady flow of information, including recommendations and guidelines for industry members. These documents and reports represent SIGTTO's accumulated intellectual property, much of which has been adopted by regulatory authorities for the governance of gas shipping and terminal activities. It represents a compendium of reference work universally acknowledged as embodying de facto standards virtually throughout every niche within the liquefied gas transportation industry.

- ✓ SGMF - The Society for Gas as a Marine Fuel (SGMF) is a new non-governmental organization (NGO) established to promote safety and industry best practice in the use of gas as a marine fuel. [9] SGMF mission includes proactively promoting safe and responsible operations for both gas-fueled vessels and gas bunker supply logistics. Additional, SGMF promotes the exchanging of knowledge and lessons learned within the industry and with regulatory authorities and

other stakeholders.

- ✓ IGU - The International Gas Union, founded in 1931, is a worldwide non-profit organization. IGU has a very broad scope across the whole gas industry, including LNG export and import. The members of IGU are various associations and entities of the gas industries in 67 countries. IGU cooperates with many global energy organizations, and covers all the domains of the industry from exploration and production of natural gas on- or offshore, pipeline and piped distribution systems to customers' premises, and combustion of the gas at the point of use. The objective of IGU is to promote the technical and economic progress of the gas industry.
- ✓ CLNG - The Center for Liquefied Natural Gas is an association of LNG producers, shippers, terminal operators and developers, energy trade associations and natural gas consumers. Based in the US, CLNG's purpose is to enhance the exchange of educational and technical information, and to facilitate the discussion of issues and the development of public policies which support the growth and operation of the LNG industry. CLNG also promotes public education and understanding about LNG by

serving as a clearinghouse for related information.

- ✓ Classification societies are independent technical organizations. Their classification of vessels assures all interested parties that each vessel is structurally and mechanically fit to carry crew and cargo. Another level of approval is certification by the societies, which provides assurance that at the time of certification the vessel is fit for service.

Vessel classification has long influenced the design, construction and maintenance of vessel structures and engineering systems. The main classification societies for the LNG carriers are the American Bureau of Shipping (ABS), Bureau Veritas (BV), Det Norske Veritas (DNV), China Classification Society (CCS), Korean Register of Shipping (KR) and Nippon Kaiji Kyokai (NK).

4.2. Codes and Standards in progress

4.2.1. Codes in progress

- ✓ United States Coast Guard Policy Letter No. 01-12 establishes design criteria for natural gas fuel systems that provide a level of



4. Codes, Standards and Industry Organizations

safety that is at least equivalent to that provided for traditional fuel systems by existing regulations.

- ✓ United States Coast Guard Policy Letter No. 02-15 “Guidance related to vessels and waterfront facilities conducting LNG marine fuel transfer (Bunkering) operations” provides guidance to owners and operators intending to conduct LNG fuel transfer operations.

4.2.2. Standards/Guidelines in progress

- ✓ ISO/DIS 16924: “Natural gas fuelling stations – LNG stations for fueling vehicles.” Under development by the working group ISO/PC 252.
- ✓ ISO/DIS 16904: “Design and testing of LNG marine transfer arms for conventional onshore terminals.”
- ✓ ISO/AWI TR 18624. “Guidance for conception, design and testing of LNG storage tanks.”
- ✓ ISO/AWI 19723-1: « Road vehicles -- Liquefied natural gas (LNG) fuel systems - Part 1: Safety requirements”
- ✓ ISO/NP 20088-3: Determination of the resistance to cryogenic spillage of insulation materials - Part 3: High pressure jet exposure



5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

Given its independence from transit countries and the increasing flexibility in its logistical chain, in combination with gas advantages such as environmental benefits and a large and growing resource base, LNG is a natural choice to help meet the world's growing energy needs. With global trade currently around 240 MTPA and an installed liquefaction capacity near 300 MTPA [10], the permanence of the LNG market as a major contributor to the global energy balance is evident.

The growth of the global natural gas market, and in particular the distribution of LNG to smaller and smaller end users, has provided access to natural gas to wide range of energy consumers. While very small in comparison to the volumes

traded within the traditional LNG value, the volumes traded within the Retail LNG value chain have allowed consumers to take advantage of new possible solutions to meet their energy needs. Building upon decades of safe, reliable and efficient transportation, LNG is shipped all over the world, making it a truly global resource. Early adopters have already started to capitalize on the availability of LNG to make a fuel switch to natural gas.

In some transportation markets such as North America, large corporate fleets and transit authorities have been the early adopters of LNG and CNG, seeking to improve their environmental profile as well as reduce costs. The marine space has seen the early conversion

of passenger ferries and small bulk carriers driven by environmental regulations and governmental initiatives. Some Commercial and Industrial (C&I) users who are not connected to the pipeline networks have moved away from the historical use of petroleum based fuels and have installed LNG storage and re-vaporization facilities to serve their energy needs. In the Exploration and Production (E&P) space, drilling operations and pressure pumping applications have started to embrace, as a replacement for diesel the use of field gas, CNG and LNG for their fuel needs.

As the use of LNG increases in the transportation, marine, C&I and E&P markets others are realizing the benefits and investigating ways to utilize LNG in their applications. High Horse Power (HHP) users in the rail and mining sectors are building upon the knowledge and experience learned in early demonstration projects to more fully realize the benefits of this emerging fuel source.

5.1 Market Drivers

Natural gas is expected to continue to be a major fuel source through for the foreseeable future driven by an interesting combination of



Figure 4 - Global LNG Flows (Source: GIIGNL)

5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

cost, environmental benefit and abundance. However, oil will remain a dominate fuel for transportation for many years to come. Natural Gas Vehicles (NGVs) only make up less than 2% of the global automotive fleet. Utilization in the marine, rail, E&P and C&I space is even less significant. However, with global total proven natural gas reserves at end-2014 standing at 187.1 trillion cubic meters (tcm), sufficient to meet 54.1 years of global production [11] , and gas prices at substantial discounts to oil in North America and Europe, the use of natural gas, and in particular LNG, may grow into new areas. The environmental benefits are significant, the technology employed is well developed, and the economics workable in many cases.

An example of an environmental market driver is the use of LNG as a fuel option for marine vessels. As described in more detail herein and in the cited references, the use of LNG for marine vessels is largely driven by upcoming changes in regulation. The International Maritime Organization (IMO) has declared that all vessels sailing in the defined Emission Control Areas (ECAs) must reduce sulphur levels in fuel oil from 1.0% to 0.1% or treat the exhaust gas to the corresponding level starting January 1, 2015. It is possible that a reduction to 0.5% sulphur

fuel could be compulsory for marine vessels worldwide by 2020 and certainly by 2025.

While the switch to LNG for marine vessels may provide economic benefit, other sectors such as over the road transportation in markets such as North America may provide better examples of how LNG could be an economic market driver. While infrastructure limitations exist, at the stations currently servicing fleets of LNG users, the LNG price typically ranges including taxes from \$2.25 to \$2.75 per diesel gallon equivalent. With medium term average diesel prices between \$3.00 and \$3.50, significant economic benefits could be realized. However, it is noted that significant headwinds, for conversions from traditional liquid fuels to natural gas that are based solely on economics, will exist for all sectors, during periods of low oil prices.

Access to competitively priced power may become another market driver for the use of LNG at small scale. Given the flexibility of the LNG value chain, LNG is being presented as a viable alternative to pipelines for power generation. “LNG-based power generation and microgrids for remote and islanded locations utilizing gas-fuelled power generation systems complemented by locally available renewable energy resources offer a potentially attractive

and cost competitive alternative to conventional solutions based traditionally on diesel power plants” [12].

As described below, market drivers for the adoption of LNG as a fuel varies from region to region. Additionally, the drivers for adoption will vary within the different end user markets. However, it can be stated that the main drivers will be environmental benefits and lower cost.

5.1.1. Market Drivers in the Americas

The combination of horizontal drilling and hydraulic fracturing, or “fracking” has allowed drillers in North America to release natural gas from shale formations that had previously been uneconomic to exploit. The effects of this technology on production and reserves have pushed prices to down. With only few local and seasonal exceptions, North American natural gas prices have traded at a discount to all other regions for the last 5 years. Favorable prices, and an abundance of reserves can make it an attractive option for fuel supply for all sectors. Since North America’s natural gas prices are set in the continental market there are few ties to world oil prices and fluctuations. Likewise, the



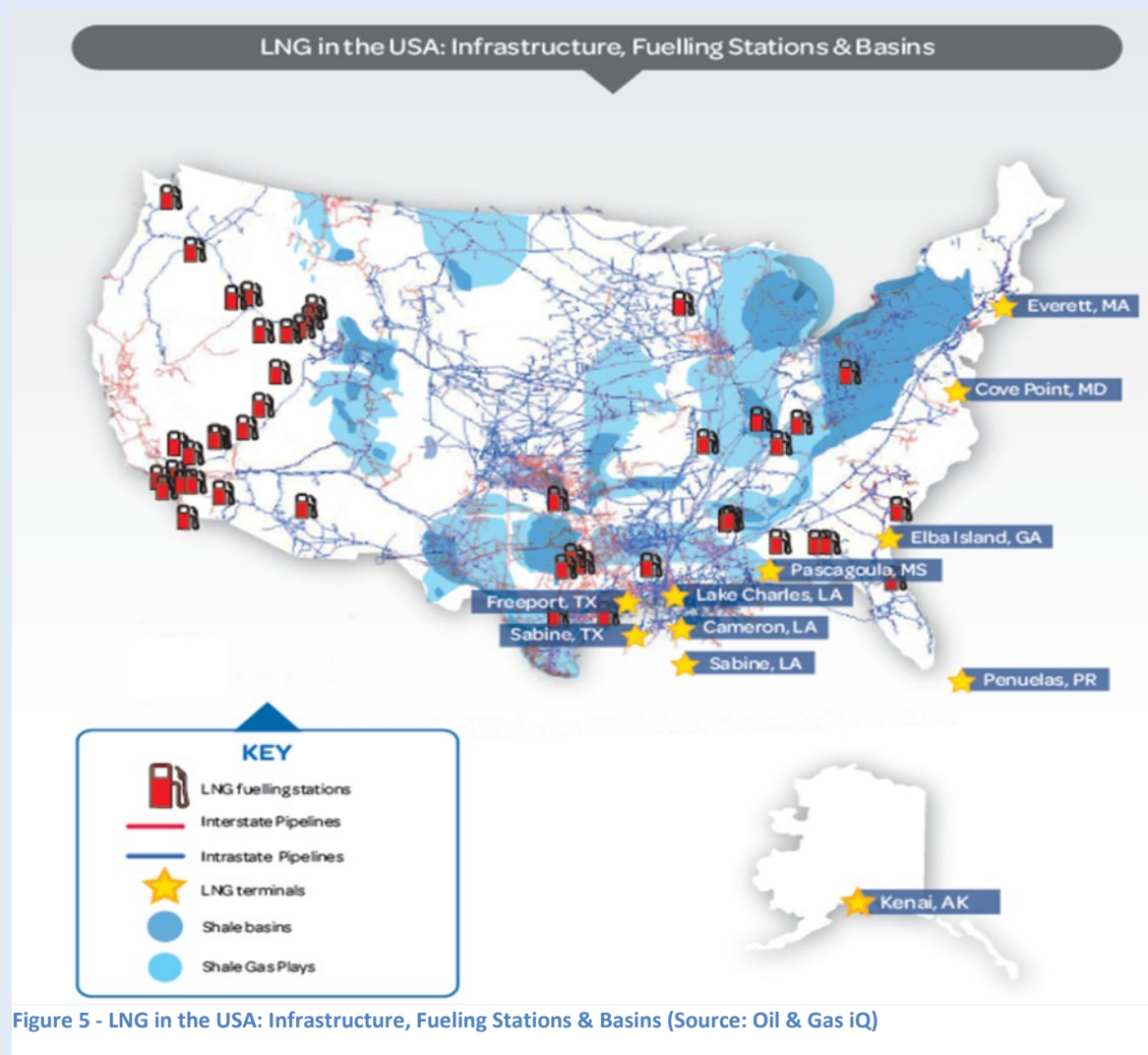
5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

price of gas in Europe or other markets will have little effect on North American pricing. However, in the context of this handbook it should be understood that the LNG trade and the role of LNG import terminals are more closely linked to both the international oil prices and the global pricing of natural gas.

Even with advantageous pricing differentials, the growth of the Retail LNG market in the Americas faces challenges. What has basically been a supply driven opportunity, the Retail market in North America has had to wait for the demand to catch up to the surplus of low cost natural gas. Demand has been further challenged by the development of other, competitive technologies such as exhaust gas after treatment which do not require a “fuel switch” to reap environmental benefits. Further complicating demand has been the downturn in the pricing of the conventional fuels. “The combination of delayed product introductions and a narrower spread between diesel and LNG pump price has pushed fuel providers to cut back on LNG station development. For example, Blu LNG opened 7 out of 9 US stations planned for 2014 while Shell (in partnership with Travel Centers of America) opened only one of three. While Clean Energy opened 11 new LNG stations in 2014, the

company has another 37 on hold [13].”

In North America there has been modest movement towards LNG for a variety of marine



5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

users including ferries, inter-coastal vessels and bulk tankers. The most visible early adopters have been LNG powered offshore supply vessels and containerships. South America has seen the deployment of an LNG powered fast ferry.

Domestic supply projects have also been delayed or canceled while others are proceeding with increased levels of “merchant” risk (i.e. unsubscribed capacity). Not counting the potential supply from Import Terminals or even Export Terminals, there is currently more than 3 MTPA of small scale LNG production being planned for North America. However, to date, projects representing only small fraction of the figure have reached Final Investment Decision (FID) and are being constructed.

In North America, if additional supply sources for Retail LNG are to be developed, it will largely be on the account of an increase in demand and reduction in merchant risk. Additional Retail LNG supply in the form of excess capacity from export projects and expansions of existing merchant facilities will likely represent the first incremental capacity in North America.

In Latin America, hydropower is the main electrical energy source for most countries with more than half of the installed capacity in the

region being hydro. The dependency and sensitivity of meteorological conditions is driving many countries to promote the use of natural gas as back up, especially for power generation.

In South America the economic drivers are more segregated depending on location. In some areas with relatively low reserves the drivers are not nearly as strong and the economic benefits of the importation of LNG will be challenged. In other areas, proven reserves have led to an imbalance of supply and demand and LNG export projects have either been built or are being considered.

Economic reforms in Latin and South America have also opened important sectors to investment by private parties. Markets traditionally reserved for the State in individual countries and in cross border multiple country regions have seen investments by third parties. Electricity generation and natural gas pipelines have been at the forefront of this liberalization,

Across the Americas the environmental benefits of switching to LNG are being considered and driving market participation. LNG provides significant benefits in terms of reducing end user emissions to the environment. “When compared with modern engines using even

“clean” fuel oils, LNG can lower [...] exhaust emission of sulphur oxides (SOx) by over 90%, of nitrogen oxides (NOx) by up to 35% for diesel cycle engines and up to 85% for Otto cycle engines; particular matter (PM) by over 85%, of carbon dioxide (CO2) by up to 29% and of greenhouse gases (GHGs) by up to 19% on a CO2-equivalent basis” [14].

Another market driver for the adoption of LNG as a fuel in the Americas is energy security. In the United States the vast majority of transportation fuel consumed domestically is exposed to global oil price risk. With this exposure, price fluctuations and spikes can have a negative impact on the economy and increase the cost of goods and services due to higher transportation cost. Latin and South America have emerged in recent years as dynamic regions for natural gas in which energy security has played a major role in policy development. The regions boast natural gas reserves and high growth energy markets. “South America has vast energy resources, both renewable and non-renewable. However, countries in the region are unable to guarantee adequate energy security levels for their consumers. The economic benefits that can be expected from the process of regional energy integration are high, but



5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

national regulations impose strong barriers to investments aimed at promoting energy integration.” [15] In recent years as energy imports from neighboring countries have proven unreliable, some market participants have found that LNG has allowed for the diversification of gas supply and bargaining power. With such success, additional participants are investigating the potential role of LNG and the energy security advantages that it may provide.

5.1.2. Market Drivers in Europe

The natural gas transmission and distribution pipeline network has been extended throughout Europe providing a reliable and cost effective way to supply gas. Major cities and high density population areas have available supply of natural gas by pipeline, allowing access to clean and affordable energy for housing and commercial business. It is, in part, the supply of high volumes of natural gas (i.e. high demand) that underpin the financial investments necessary for the expansion of the natural gas pipeline network and its upkeep.

The necessity of increasing the demand of natural gas, as a way to reduce emissions of greenhouse gases is a driver that requires extending the availability of natural gas to new

customers. However, that policy is becoming more and more challenging: potential clients are further and further away from existing pipeline networks and the demand is many times too low to justify the required investments for the expansion of those networks. When the topography and geography is challenging, demand is even more difficult to service by pipe.

In addition to motivation to reduce emission of greenhouse gases the use of natural gas in transportation, has become an European market driver for Retail LNG. In Europe, LNG is increasingly becoming a final product, whether it is used directly or to produce CNG. Natural gas is more and more considered a real alternative to traditional fuels. Furthermore, LNG to date has been the only substitute for diesel in long haul road transport and in ships. The European Union, by means of the Directive 2014/94/EU, has stated that member states must develop an appropriate number of refueling points of LNG to vehicles and ships, as well as a sustainable logistic chain. Additionally, the European Parliament has issued its advice on the oncoming Energy Taxation Directive including the exoneration of CNG, partially or totally, from taxation until January 1, 2023.

The European Union has initiated a massive

financial support program in order to motivate users to change to greener fuel alternatives. The Connecting Europe Facility (CEF) finances projects which create the trans-national European infrastructure in energy (TEN-E), transport (TEN-T) and digital networks. CEF is a combination of EU funds, and has around 26 billion EUR for transport infrastructure in the period 2014-2020. The CEF promotes cleaner transportation modes and facilitating the use of renewable energy. CEF has a large allocation for

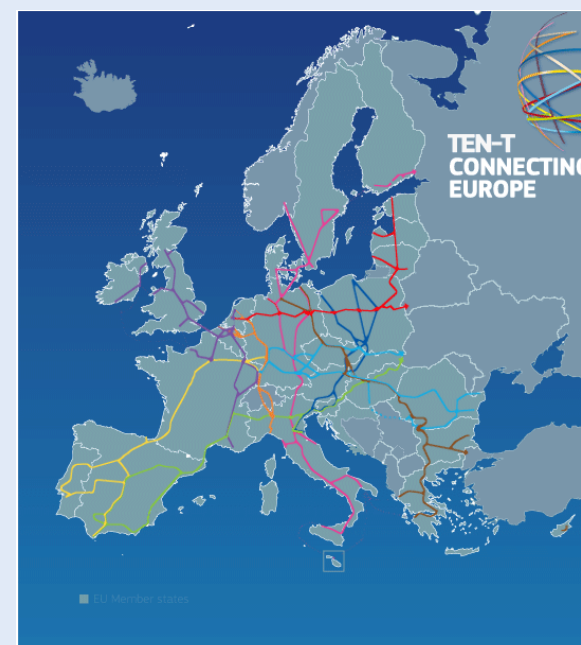


Figure 6 - TEN-T Core Network Corridors (Source: European Commission)

5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

the Motorways of the Seas, with an expected emphasis on clean maritime transportation.

On September 18, 2014 Ministry of Employment and Economy of Finland committed a total of EUR 65.2 million in energy subsidies for the construction of three liquefied natural gas (LNG) terminals. With the help of this support three contractors, Manga LNG Oy, Skangass Oy, and Oy Aga Ab will build LNG terminals in Tornio, Pori and Rauma respectively. The new LNG facilities are intended to help facilitate a move to significantly reduce the industrial use of fuel oil and liquid petroleum gas (LPG) in Finland

[16].

Therefore, Retail LNG is posed to play an important role in the expansion of the traditional uses of natural gas, and in the challenge of reducing the Europe's over-dependence on oil in transportation.

At the operational level, Retail LNG logistic chains may be considered part of the offered services by the existing LNG terminals or as services offered by third parties who have arranged access to existing terminals or are developing their own Terminals. Distribution of LNG from main EU import terminals to smaller regional and local terminals will improve security

of supply and market functioning in the EU, as well as enable a cost-effective way of supplying natural gas where adequate network connections are not available [17].

A good example of supplying LNG via road trailers, if not the best, is the experience of Spain: since the first truck was loaded in 1970 in the Barcelona Terminal, up to 45,000 trucks per year have transported LNG. Shipments from Spanish LNG terminals have had destinations not only within the country, but also throughout greater Europe. Destinations of LNG include industrial clients, local distribution companies and housing. Capital cities like Albacete or

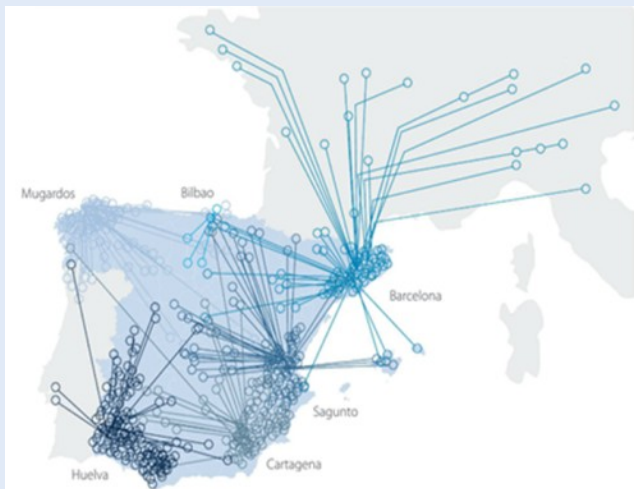


Figure 8 - Destination of LNG from Import Terminal (Source: Informe Gasista Español 2014. ENAGAS GTS)

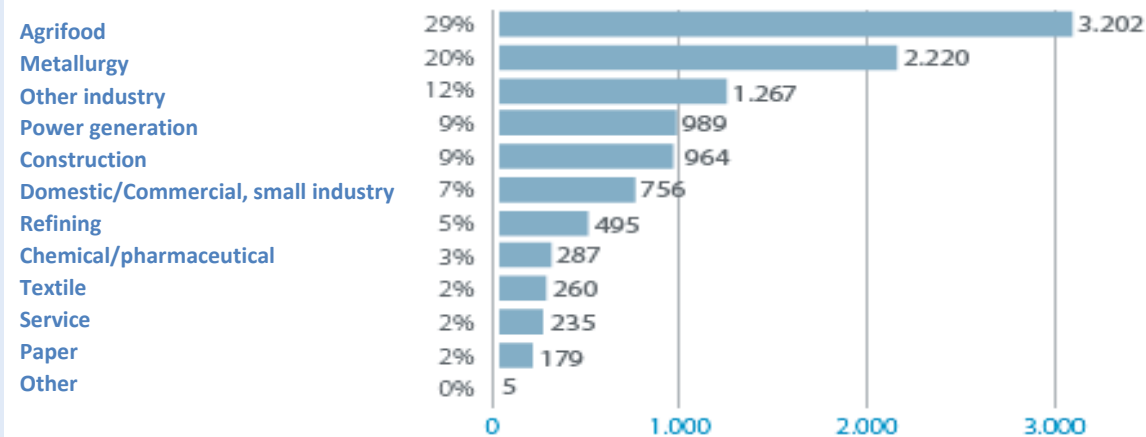


Figure 7 - Market Segments (% adn GWH) of retail LNG from Spanish Terminals (Source: Informe Gasista Español 2014. ENAGAS GTS)

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Almería have been supplied by trucks without having any significant incident.

In 2014 alone, the truck movement from Spain account for the 85% of the total in European Union. The utilization by market segment could be seen in Figure 8.

For illustrative purposes the following figures for 2014 are presented:

- ✓ LNG delivered: 10.9 TWh.
- ✓ Km driven to delivery points: 8,154,547.
- ✓ 788 satellite plants supplied.

Another good experience of Retail LNG is the case of Madeira Island. In 2014 a LNG logistic chain was established that supplied natural gas to power plants in the island from the Sines LNG Import Terminal. In this example, LNG ISO containers are loaded in the REN facilities, and transported by truck to the port of Lisbon. Then, containers travel more than 950 km by sea and distributed in the Madeira Island by truck again.

In areas like the Baltic region the main driver for promoting small scale LNG, is the introduction of new reduced emission requirements from the marine transportation sector. As from January 2015 the ultra-low sulphur requirement set by the International Maritime Organization (IMO) is

introduced in the Emission Control Area (ECA). In addition, EU has a strong focus on reducing the emission from the transportation sector in general, and is supporting infrastructure projects to develop the LNG small scale market.

As from 1 January 2015 ships sailing in the ECA area, see Figure 9 - Baltic Region ECA Zones, are required to use a fuel with ultra-low sulphur content (i.e. 0.10% by weight), or alternatively use of exhaust gas cleaning systems also called scrubbers, which will ensure same amount of SOx emissions. Compliance by the use of ultra-low sulphur content MGO could imply a significant premium per ton of fuel used, but no

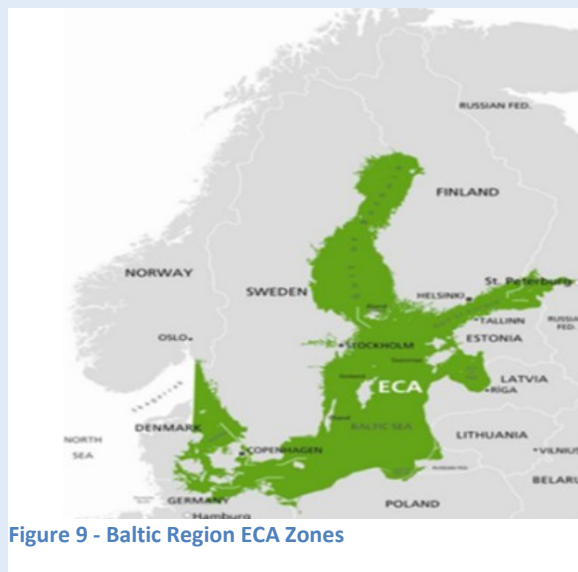


Figure 9 - Baltic Region ECA Zones

capital investment is required. Conversion of existing ships to use LNG as its main fuel is expensive. In addition there is presently an obvious lack of supply network.

LNG is an attractive fuel option for vessels in particular to meet the new limits for sulphur content in marine fuels. These obligations will be relevant for about half of the 10,000 ships currently engaged in intra-EU shipping. LNG is an attractive alternative also for shipping outside SECA, where sulphur limits will decrease from 3.5% to 0.5% from 1 January 2020, and globally.

Lack of fuelling infrastructure and common technical specifications on refueling equipment and safety regulations for bunkering hamper market uptake. [18] To convince the ship-owners to use LNG in the shipping segment instead of other emission mitigation measures such as scrubber technology are challenging. Two important issues are on the agenda: the availability for LNG as bunker and the future price spread between oil and gas (LNG). At this stage, there are a lot of plans in the Baltic area, however even with strong financial support from EU, and also independently from governments (in particular Finland) it seems difficult for many to set up a complete LNG value chain. The suppliers require longer commitments from the

5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

buyers in order to reduce the risk for the investment while historically, the ship owners have purchased bunkers on a spot basis and hesitate to sign up for longer contracts. However, even in the face of these challenges ,already three LNG Import Terminals (Gate Isle of Grain and Zeebrugge) are constructing jetties designed to supply small scale markets, including bunkers. Also, three companies (Shell, ENGIE and Skangass) have placed orders for bunker barges to supply LNG as bunker fuel in the North Sea and Baltic Sea area.

In Europe, as in other parts of the world, the containership and car ferry market segments are

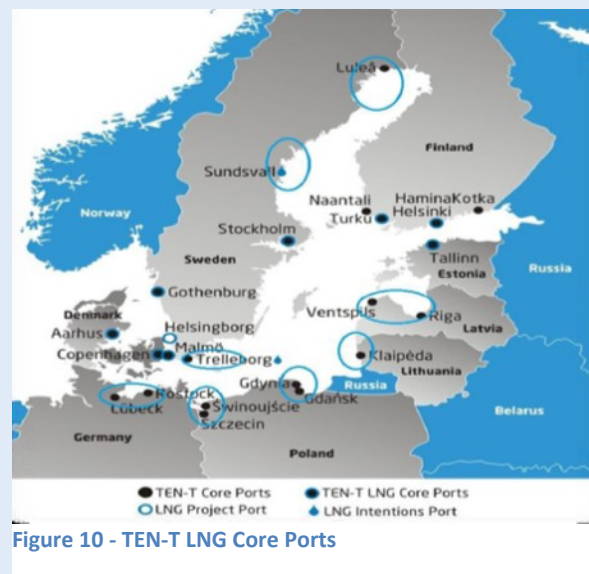


Figure 10 - TEN-T LNG Core Ports

apparent potential customers for LNG propulsion. These customers generally require bunkering during loading/unloading so it is important to develop procedures are requirements which allow for this activity in this area. The ability, or inability, to develop LNG value chains in which these “simultaneous operations” are allowed will be an important factor in the large scale adaption of LNG as a fuel.

In addition to Marine activities in the Baltic, and other European areas, there is a market for LNG for industrial customers. Examples include the Finnish and Swedish sector which are not connected to the gas pipeline grid and are using fuel oil in their energy mix like iron ore, mining and metal industry. It is envisaged that this market segment will develop hand in hand with the LNG for marine transportation, require more intermediate storage and more feeder vessels in operation. Similar to what has been described in the Spanish market above, other areas in Europe have seen established and new LNG operators such as Primagaz, Axegaz, Butagaz, Gas Natural Fenosa and LNGeneration delivering small volumes of LNG to off-grid customers.

Throughout Europe, as in other parts of the world, the alignment of demand and supply will

continue to pose significant challenges and require innovative solutions if the Retail market is to grow significantly. “A dilemma exists between the level of LNG demand and the availability of LNG supply and distribution, with owners on both sides of the business depending on the other to anchor new investments. As a result, cooperatives and partnerships are being formed to mitigate commercial risks, align business interests and move supply and demand projects forward in parallel” [19]

5.1.3. Market Drivers in the Far East

Similarly to other countries such as Spain and the United States described herein, Japan has had a long and successful history of moving LNG over land to remote customers. The genesis for this activity lies more with the concept of “satellite terminals” and the extension of the domestic gas transmission system, than it does with direct commercial sales to “end users”.

In Japan, the LNG import terminals are generally located in the major consuming regions of metropolitan areas. Although it is a normal work to store and vaporizer the LNG from the important terminal’s tanks for injection into

5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

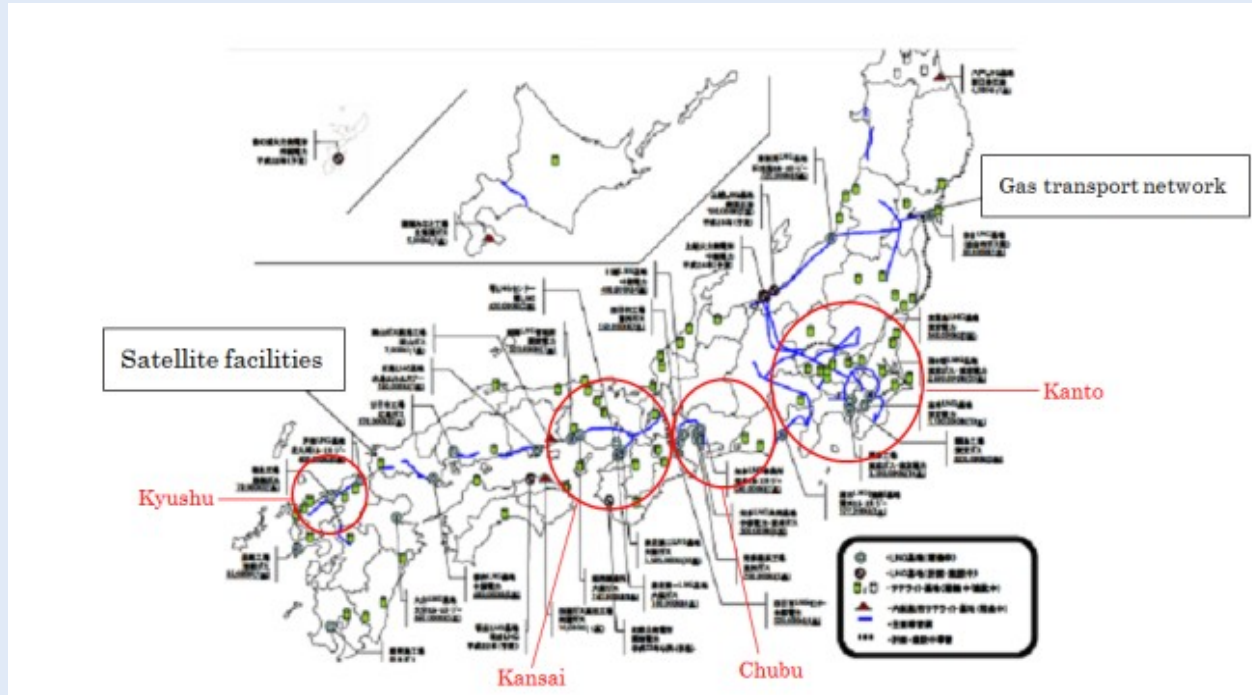


Figure 11 - Satellite Facilities and Gas Transport Network (Source: Ministry of Economy Trade and Industry)

regional pipelines as is done in most parts of the world, Japan does not have an adequate pipeline network to transport the natural gas from LNG terminals to end users. Historically, numerous city gas utilities, or local distribution companies have existed separately by supply areas. The primary reason why these supply areas did not link together might be explained by Japanese topography of which mountains comprise 70% of the national land. Only Kanto,

Kansai, Chubu and Kyushu regions had improved pipeline connection between end users and LNG terminals. Consequently, Japan had to develop the satellite facilities of gas transport network of receivable tanks to end users.

In case of Kanto region, Tokyo Gas transports LNG by LNG trailer to the satellite facilities from Negishi or Sodegaura terminal up to a maximum distance of 200km. These areas do have an

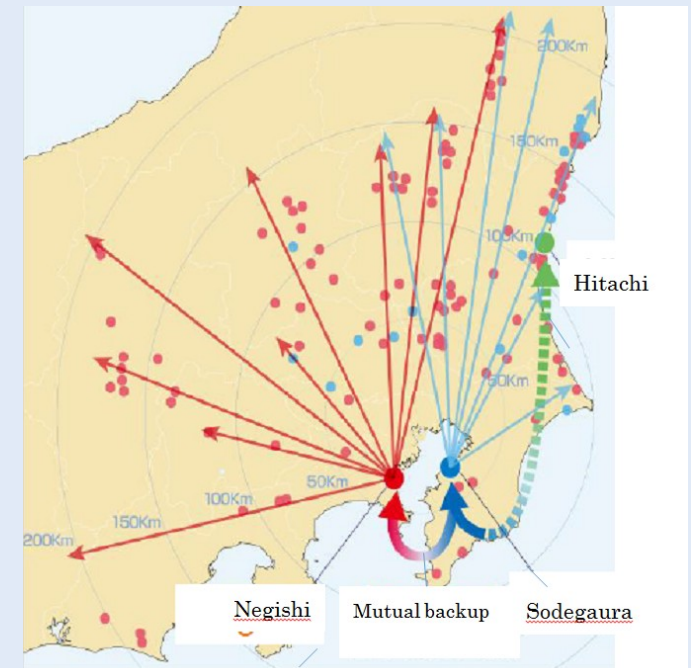


Figure 12 - Distance of Satellite Transport System in Kanto region of Japan (Source: Tokyo Gas [68])

established distribution pipeline network, however, in some cases the distribution pipeline cannot transport enough natural gas to the end users in terms of volumes and/or pressure. Even if volume of natural gas were available in some cases there is no pipeline lateral to transport natural gas all the way to the end users. Hence the advanced LNG satellite transport system is required along with the pipeline distribution network. LNG satellite terminals receive LNG

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and vaporizer the LNG within the terminal and distribute for local utilities and industries or transmit to power plants.

The excellent road transportation infrastructure available to move goods throughout Japan, coupled with the high cost of pipeline construction have, and are expected to continue to drive LNG activities at very small scale.

Additionally, in Japan ISO containers have also been used for multimodal transport by railway service and land transport service. In 1973 LNG was transported by freight train for the first time from Negishi to Hitachi. ISO containers were previously used for sea transport between Kanto and Hokkaido. Presently freight train can transport LNG over 300km from Niigata to Kanazawa as well as from Niigata to Akit-Aomori. The Japan market has experience that would indicate transportation via freight train over longer distances than normally supplied via LNG truck transport is viable.

In addition to transportation via LNG trailers or freight train, LNG coastal carrier can also be used for 2,500 -3,500 m3 size of LNG transport. In 2003, the first LNG by coastal carrier was transported from Kyushu to Takamatsu. Presently this case can be observed typically



Figure 13 - Coastal carriers and freight trains in Japan

from Sodegaura terminal to Hachinohe terminal as well as from Himeji or Tobata terminal to Takamatsu or Matsuyama terminal.

Concepts utilized such as the “hub and spoke” distribution chain now being utilized by many participants in the Retail LNG value chain have been well proven in Japan. As “end use” technologies come to market, such as engines for marine vessels and over the road trucks, the

robust infrastructure and operational and logistical experience within Japan should make adoption and proliferation of Retail LNG manageable.

Investment by China in smaller LNG facilities will be driven by the use of LNG to fuel vessels and vehicles that will require investment in LNG bunkering facilities and fuelling stations. Stricter emission standards are pushing growth in both

5. OVERVIEW OF THE CURRENT RETAIL LNG MARKET

these areas; however, the market's value will reach its highest point during the construction of small scale liquefaction plants and terminals in China [20]. By 2020, the total installed capacity for Small Scale LNG plants in China is expected to reach 21 MTPA [19]. Additionally, recent announcements by the China's Ministry of Transportation indicated that major efforts are underway to cut sulphur dioxide emissions from ships in the Bohai Sea, the Pearl River Delta and the Yangtze River potential creating Emission Control Areas. Reports indicated that "Ship and Port Pollution Prevention Special Action Plan (2015-2020) actively promotes the use of LNG as primary marine fuel [21].

The observed growth and future prospects within China are driven not only by the stricter emission standards, but also the availability of domestic gas and state controlled natural gas pricing mechanisms that provide attractive spreads between diesel and natural gas. GIIGNL has found it challenging to provide exact figures for the scale and scope of the Chinese Retail LNG market. However, at the issuance of this Handbook GIIGNL estimates that there are more than 120 small LNG production plants in operation, 140,000 LNG fueled trucks and 2,300 LNG fueling stations throughout China.



Figure 14 - Botas LNG Terminal LNG Loading Rack
(Source: Botas)

Initially driven by a desire to diversify supply sources by improving the security of supply and flexibility of procurement Turkey has built experience in the LNG business [21]. Part of that experience has been with the over the road distribution of LNG to remote users. GIIGNL member Botas has loaded close to 200,000 trailers for distribution to the domestic market from their LNG terminal. The activity demonstrates once again, the viability of utilizing large LNG import terminals for the supply of LNG at small volumes.

Bunkering for marine vessels in South East Asia has recently been receiving significant attention. In Singapore, the Maritime Port Authority recently announced that they would be ready for LNG bunkering no later than 2020 and is seeking proposals for LNG supply. Unlike in

North America and Europe where the compliance with the ECA zones is a primary driver of LNG adoption, with the exception of Hong Kong no such environmental restrictions exist in South East Asia. However, a port like Singapore which is one of the world's leading bunkering hub, appears to be positioning themselves for the world's next generation fleet.

With existing LNG experience and large scale LNG Terminals existing, or under construction, countries such as Korea, Thailand, India and Indonesia may be well poised to embrace Retail LNG should economic or environmental market drivers present themselves.

5.2 Value Proposition

The commercial case for Retail LNG rests on a number of economic and regulatory factors. Economic factors include the price differential, or spread between fuels compared to the additional investment, capital cost of equipment and infrastructure, availability of LNG supply and increase in demand that will determine not only the growth of the Retail market, but the value to participants. LNG for the Retail market, for the vast majority of applications, represents an alternative fuel source to the fuel currently

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being consumed by the end user. Liquid petroleum fuels are the de facto source of fuel for the end users contemplating the use of LNG. Historically, consumption and pricing of natural gas and petroleum based fuels traded in sync with one another. In markets such as the United

States, “one of the most important recent trends has been the decoupling of natural gas and petroleum prices” [22]. In Europe natural gas and petroleum are formally decoupled, although a close correlation still exists. In northern Europe pricing of natural gas is done through gas

hubs such as TTF and NBP, where a well-functioning liquid market for natural gas exists and oil indexation is becoming rare in new contracts. In southern Europe gas markets are less liquid and there is still a strong reliance on oil indexing. Until very recently, surplus natural

Illustrative Example – Gate LNG Terminal, Rotterdam Netherlands

Operational since 2011, the Gate Terminal has been designed as a base load regasification terminal with two jetties and 540,000m³ of storage. Gate terminal is an open access terminal where five capacity users have long term positions for the import of LNG. At the two existing jetties both unloading, reloading and transshipment operations are offered for LNG vessels ranging from 6,000m³ up to Qmax size.

Currently a third jetty is under construction, designed and constructed as a dedicated jetty for the small scale LNG market serving LNG vessels of 1,000m³ up to 40,000m³. Gate’s expansion with this new jetty is supporting the developing small scale LNG market in Northwest Europe and will be operational in 2016. Gate is then offering firm services to supply LNG to industrial and shipping customers in the heart of Europe’s largest bunker port.

Since early 2014 Gate is also offering truck loading services, where up to 4,000 road tankers and ISO containers can be filled with LNG every year. These volumes are used for off grid industries, as shipping or trucking fuel. Part of the volume is supplying the 15 LNG retail stations for trucks in the Netherlands or one of the several inland waterway ships sailing on LNG, and the rest is distributed across Europe either by road truck or onwards by ship or rail connection.

All services offered by Gate are open to third parties: customers using either the truck loading service or the small scale jetty work with Gate to contract the infrastructure service, and can then choose one of the five capacity users who have long term LNG import positions in to act as their LNG supplier. By offering open access infrastructure services to the small scale market, Gate is able to benefit from its strategic location in Europe’s largest bunker port to serve both small scale and large scale LNG markets.



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gas and tight petroleum supplies led to historic divergence in the prices of the fuels. Even with the recent downturn in global oil prices, spreads remain attractive enough to operators of high horsepower applications such as vessels, mining, rail, and over the road transportation to continue investments in LNG infrastructure.

Additional value can be derived for end users as LNG has potential environmental benefits that reduce local emissions, while avoiding complex operational and commercial measures associated with emission control processes.

In 2012, the American Clean Skies Foundation published a paper which investigated the use of natural gas for marine vessels. An important conclusion of this work was that economics of any specific project will hinge on three factors: vessel fuel use, delivered LNG prices and vessel conversion cost [23]. While the report was focused on marine vessels, other sectors within the broader “Retail” LNG market have witnessed the same three factors driving projects; how much fuel is consumed, how much does the fuel cost and what does it cost to upgrade or convert in able to consume natural gas.

Although most forecasts indicate that natural gas pricing is expected to remain at a discount

on an energy comparable basis to liquid petroleum fuels, the cost of LNG liquefaction and distribution can essentially triple the cost of the delivered natural gas in a market like the United States. However, the fuel can still be attractive, relative to most of the projected prices for liquid petroleum prices. In the marine market over the next ten years, delivered LNG is projected to cost at least 41% less than residual fuel and 57% less than distillate fuel per unit of

energy delivered [23].

For LNG import and export terminals these market dynamics are creating interesting opportunities to expand their services. Since large investments in marine facilities and storage have already been made in these facilities there is the potential to have economic advantages over new market entrants. Additions of small berthing facilities and loading bays for trailers,

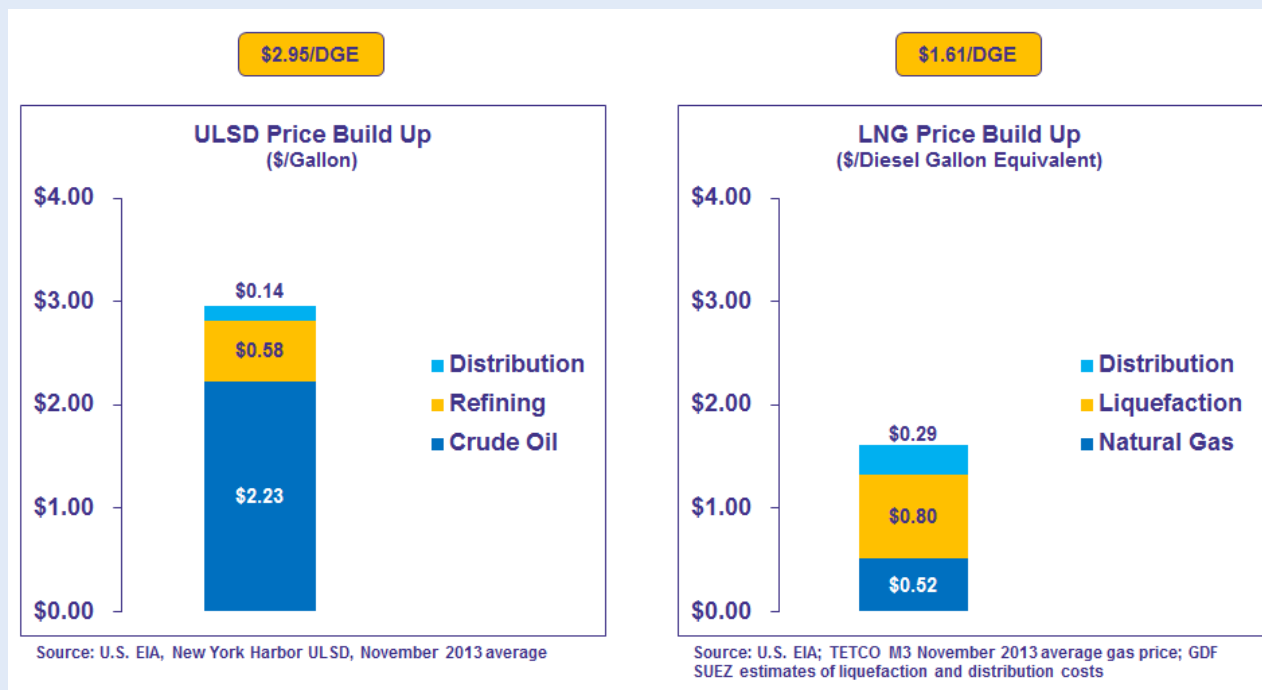


Figure 15 - Diesel and LNG Price Build Up (Source: ENGIE)



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rail cars, and ISO containers are considered minimal in contrast to building from scratch facilities with similar capabilities.

While Figure 15 has been provided for illustrative purpose, it should be noted that pricing will, and has, fluctuated greatly. Participants in the Retail LNG market should pay close attention to the pricing “build up” and recognize the underlying fundamentals that contribute to any spread between LNG and traditional fuels. Likewise, Figure 15 only represents a recent condition within the United States. Regional differences in the pricing of fuels, taxation, and cost of distribution will play a critical role in defining the value proposition of LNG within markets. For example a recent observation at a European fueling station serving both diesel and LNG trucks, revealed diesel prices are 1.35 €/l and LNG prices are 1.25 €/kg which results in a spread that is far less than what has been indicated in Figure 15.

When considering the “value proposition” of LNG as a fuel it is important to note that there currently are situations in which the value proposition comes down to nothing more than being able to stay in business in areas in which environmental mandates are driving LNG adoption.

As detailed more fully herein, GIIGNL has decided to address some of the complexities regarding the value proposition of Retail LNG in a second Phase of this Handbook. GIIGNL’s Commercial Study Group will help to address in more detail some of the thought-provoking commercial considerations faced by participants in the Retail LNG market.



6. Equipment Utilized in the LNG Process Chain

As described herein, the Retail LNG value chain is in essence, an extension of the larger LNG trade that has been well established for decades. As such, many of the systems used in the Retail LNG value chain contain specific components which have been utilized in LNG service for many years, while others are being repurposed for the needs of the Retail LNG market.

The following sections provide an overview of the types of equipment that have been employed to date, and can be employed going forward, as the Retail LNG market expands. Although focused primarily on the equipment utilized within LNG Import Terminals, many of the details are applicable throughout most Retail LNG value chains, including those that do not include an LNG Import Terminal as a supply point.

While extensive, the listing of equipment and components may not encompass all possible solutions that may be employed in Retail LNG trade. GIIGNL provides details on the following not to select preferential equipment or components, but to provide an overview on the landscape of LNG equipment availability and use.

The practical issues and requirements provided can be used to help guide and facilitate a skilled operator team to work out suitable solutions for Retail LNG applications. All such solutions would be subject to detailed engineering work.

No particular manufacture of equipment is recommended or implied suitable for any specific purpose in this Handbook. Readers should ensure that they are in possession of the latest information, standards and specifications for any system, component or specific piece of equipment they intend to employ and work closely with vendors, engineers and other technical specialist to ensure that the selection of such is appropriate for the given application.



Figure 16 - LNG trailer loading (Source: ENGIE)

6.1 Production Equipment

In basic terms, production of LNG requires the exchange of heat/cold between natural gas and a refrigerant cold enough to cause liquefaction. There are many choices of refrigerants whose properties allow for cooling of natural gas to the required temperatures. They generally fall into two groups: mixed refrigerants (MR) or single component refrigerants. Single component refrigeration systems boast simplicity and ease of operation as key benefits. However, the most efficient liquefaction processes are those in which the refrigerant possesses a thermodynamic cooling curve that closely matches that of the natural gas being liquefied. Mixed refrigerant process have the ability to be optimized based upon the natural gas composition and can better match the cooling curve of the natural gas without needing the refrigerant to operate at multiple pressures. Consequently, the use of MR process usually yields higher overall process efficiency. With more than 80% of the installed liquefaction capacity employing some form of MR process, the LNG market has demonstrated the commercial importance of high efficiency.

However, efficiency, while important, is not the

6. Equipment Utilized in the LNG Process Chain

only factor to be considered by those bringing LNG capacity to the market. For smaller facilities capital cost, schedule, inherent safety, regulatory and permitting considerations may be more important than the efficiency advantages of more sophisticated processes.

Over the last 40-50 years only a handful of distinctive liquefaction technologies have been employed at the world scale LNG liquefaction facilities. Today the basic processes employed are:

- ✓ Propane Pre-cooled, Mixed Refrigerant (C3MR) - The most common large-scale process for the liquefaction of natural gas achieves higher efficiency and capacity per train than SMR processes by adding a pre-cooling loop, utilizing a pure propane refrigerant, to reduce the flow rate of MR and debottleneck the compression system.
- ✓ Dual Mixed Refrigerant (DMR) - Replacing the pure propane refrigerant used for pre-

cooling in the C3MR process with a second MR cycle reduces footprint and propane inventory, making DMR attractive for floating liquefaction facilities.

- ✓ AP-X® - APCI's process uses a nitrogen expander loop rather than MR to sub-cool LNG produced in either a C3MR or DMR process. The resulting reduction in propane and MR refrigerant flow rates allows substantially higher production without the need for larger compressors or heat transfer equipment.
- ✓ Optimized Cascade© - Conoco-Phillips' process utilizes a succession of single component refrigeration loops (typically using propane, ethylene and methane) to progressively cool and liquefy natural gas. The process uses multiple smaller compressors and drivers to deliver high availability and flexibility.

Smaller facilities that have economic drivers besides overall efficiency (i.e. lowest cost of

production), have successfully employed a variety of simpler processes. Most of these processes have equipment counts far lower than the facilities used at world scale export facilities and are far less complex leading to a simplification of controls and operations.

- ✓ Single Mixed Refrigerant (SMR) - Uses a single closed-cycle refrigeration loop to pre-cool, liquefy and sub-cool the natural gas. The main exchanger is typically a simple plate-fin unit designed to offer a liquefaction system, which although not as efficient as the world-scale processes described above, has a lower capital cost and is easy to operate. Furthermore, improvements to the SMR process have resulted in modern plants requiring 25 to 35 per cent less power than older facilities. Many proprietary SMR designs are available from a variety of licensors. N2 Expander - The process uses the reverse Brayton cycle to create refrigeration by compressing nitrogen, removing the heat of compression,



Figure 17 - LNG Process Trains – Relative Capacity in MTPA

6. Equipment Utilized in the LNG Process Chain

expanding the nitrogen through a turbo-expander to create a cold stream, and warming the stream against the heat load. On average, the N₂ expander cycle requires approximately 30% more power than the SMR cycle [24], but generally has lower capital cost.

- ✓ Dual N₂ Expander – Similar to the single N₂ expander this process utilizes nitrogen as refrigerant. Two expander/boosters (warm and cold) are used with a single main heat exchanger to more closely match the cooling curve of the natural gas.
- ✓ Open Expander - In this process, 85 - 90% of a high pressure feed gas stream is expanded and the resulting cold energy used to liquefy the remaining 10 - 15%. The stream of low pressure expanded gas must be disposed of and hence, plants are often located where feed gas can be taken from a high pressure main and tail gas delivered to a low pressure local distribution system.
- ✓ Sacrificial Nitrogen – In areas where liquid nitrogen is readily available and commercially attractive, the use of sacrificial nitrogen may be feasible. In this process liquid nitrogen is transferred to a heat exchanger. The heat exchanger also receives

natural gas that has been processed. The natural gas is liquefied by free cold from the liquid nitrogen so that LNG is produced.

In addition to the differences in the thermodynamic cycles employed at the smaller scale facilities, different types of equipment may be selected for operational reasons, such as maintenance or reliability: reciprocating and screw type compressors may be preferred to the centrifugal compressors found in the larger MR systems, drivers may be electric in lieu of turbines, plate fin heat exchangers may be utilized in place of coil wound exchangers. [10]

6.2 Storage Equipment

Within the LNG process chain different concepts for storing LNG are applied depending on variety of factors including, but not limited to storage volumes required by the market, local conditions, available space, permitting and regulations, etc. Storage tanks can be grouped into two basic categories: atmospheric and pressurized.

The storage of LNG at essentially atmospheric pressure (pressures below 0.5 barg) in large flat bottomed tanks is well established and comprehensively regulated by code. Traditional

LNG export and import terminals will use one of the following designs to meet their storage requirements:

- ✓ Single containment - Single containment tanks typically feature a primary liquid containment open-top inner tank, a carbon steel primary vapor containing outer tank and an earthen impoundment berm for secondary liquid containment.
- ✓ Double containment - A double containment LNG tank is designed and constructed so that both the inner self-supporting primary container and the secondary container are capable of independently containing the liquid stored.
- ✓ Full containment - Full-containment tanks typically feature a primary liquid containment open-top inner tank and a concrete outer tank. The outer tank provides primary vapor containment and secondary liquid containment. In the unlikely event of a leak, the outer tank contains the liquid and provides controlled release of the vapor.
- ✓ Cylindrical full containment membrane – Predominantly used in Japan and Korea membrane tanks utilize a thin stainless steel corrugated membrane for the primary



6. Equipment Utilized in the LNG Process Chain

container. The secondary container is a pre-stressed concrete tank. The space between primary and secondary container is filled with thermal insulation.

- ✓ Non-cylindrical membrane – The transferring of technologies from the LNG shipping industry is leading to the potential emergence of onshore membrane storage which could bring the benefits of prefabrication and modularization while still maintaining the general characteristics and performance of atmospheric storage.
- ✓ In-Ground – Tanks of this design are mainly used in Japan and some other Asian countries. They were developed by Tokyo Gas Engineering (TGE) in the early 1970's based on earlier designs in the UK, the US and Algeria and subsequently used by other Japanese companies. These tanks do not need to be surrounded by a dyke or bund wall, so the separation distance from adjacent land is less than that of other types of tanks.

Upon examination of the design details of the above flat bottom tank designs and a review of related codes, standards, regulations, procedures and related systems, it can be ascertained that in LNG export and import

terminals the overriding philosophy for storage is to have more than one layer of containment. The addition of leak detection and protection systems, in most installations, further enforces the high level of risk mitigation employed at these facilities.

The emerging Retail LNG market is indicating that required storage volumes for even the largest users only account for a small fraction of the total storage usually found in export and import terminals. Although the characteristics and risk of the LNG are similar, the smaller volumes of LNG being handled, stored and transferred present some different criteria for evaluation.

The Retail LNG value chain requires the storage and frequent transfer of relatively small volumes of LNG. Throughout these processes LNG will absorb heat from the atmosphere, warm piping and process equipment, such as pumps. As the temperature of the LNG rises, it will begin to boil, producing 'boil-off gas' (BOG), which must eventually be removed to maintain the pressure in the storage tank within safe operating limits. As a result, the Retail market has seen a trend towards the use of pressurized storage that enables the boil-off gas to be retained inside the tanks for longer than with atmospheric tanks.

The resultant higher storage pressure also raises the boiling point of the stored product, further helping to reduce rate at which BOG is generated.

Pressurized LNG storage vessels are designed and built to the requirements of recognized codes and standards (e.g. ASME Boiler and Pressure Vessel Code and EN 13458). They typically store product at pressures of between 2 and 4 barg and have design pressures of around 10 barg. Most vessels are double-walled vacuum insulated bullets, with the exact form depending on the application: LNG trailer tank; LNG Refueling Station storage tank; ISO Container for inter-modal transportation and IGC Type-C tanks for LNG bunker barge and small carriers.

In addition to the use of pressurized storage, transfer and storage operations should be managed such that BOG generation is minimized and any BOG removed from the storage system is captured (through the use of compression or re-liquefaction) to eliminate the need for venting or flaring.

6.3 Transfer Equipment

For the Retail LNG market, the safe transfer of



6. Equipment Utilized in the LNG Process Chain

LNG from storage into transportation at the supply location and the transfer back out of transportation to end users will be of critical importance. Minimizing the risk of spill during LNG transfer operations throughout the LNG value chain should be paramount for all participants. Many valuable lessons from the broader LNG industry can be applied. Likewise, many of the system components to ensure safe transfer operations have been made smaller to accommodate the lower flows associated with the Retail LNG market.

LNG can be transferred to vessels, trailers, rail cars, etc. from storage using one of two methods. LNG in storage can be transferred via differential pressure in which the pressure of the LNG storage is higher than that of the receiving vessel¹. When storage pressures are less than the pressures of the receiving vessel¹, cryogenic transfer pumps can be employed. These pumps will generally be submerged motor pumps located with the storage tanks or within “pots” or external pumps commonly referred to as “ground pumps”. These pumps are generally installed at the storage facility but in some cases they have been mounted on the vessel or trailer

¹ “Vessel” is understood to mean any type of storage used in transportation (i.e. cargo tanks within vessels, trailers, rail cars, etc.)

used to transport the LNG

Facilities employing pressurized storage may be able to benefit from the inherited capabilities of bullet tanks to achieve suitable transfer rates using differential pressure without any mechanical assistance. Large facilities such as some LNG Import Terminals may have the advantage of having LNG headers, feed by existing pumps, used for normal operations with suitable operational pressures for loading operations.

6.3.1 Marine Transfer Equipment

The transfer of LNG between transport vessels and storage or from storage to vessels, can be accomplished by various means. Traditionally, the transfer of LNG from large liquefaction plants to vessels has been accomplished with the use of dedicated marine transfer arms. These ridged loading arms employ swivel joints that allow for the transfer of LNG with some movement of the moored vessels. In most applications three or four loading arms are used to transfer LNG and one arm is used to return the LNG vapors. These marine loading arms have demonstrated an excellent and reliable experience record.

These articulated arms are also usually fitted with Quick Connect Disconnect (QCDC) systems that allow for rapid connection and disconnection during normal operations. For the disconnection, the QCDC can work with an Emergency Shutdown (ESD) system to quickly and safely close off LNG flow and decouple the arms. Commonly referred to as a Powered Emergency Release Collar (PERC) the integrated use of two valves and a release collar allow for the decoupling of the arms from the vessel with essentially no release of product to the atmosphere. The design of the arms will take into account such parameters as LNG flow,

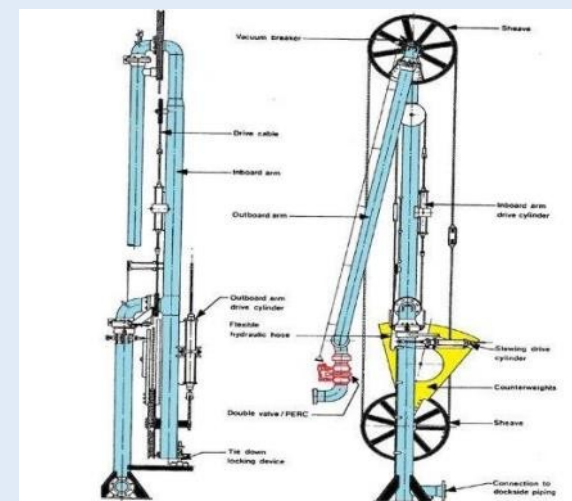


Figure 18 - Marine Transfer Arms (Source: Marine Insight [64])

6. Equipment Utilized in the LNG Process Chain

pressure, tidal conditions, wind loading, earthquake loads, manifold spacing, ice buildup, as well as a host of additional site and condition specific criteria.

Documents and Specifications such as the Oil Companies and International Marine Forum (OCIMF) “Design and Construction Specification for Marine Loading Arms”, The Society of International Gas Tanker and Terminal Operators “Manifold Recommendations of Liquefied Gas Carriers” and EN 1474-1 and EN 1474-3 “Installation and Equipment for Liquefied Natural Gas, Design and Testing of Marine Transfer Systems” should be consulted.

The emergence of offshore liquefaction and regasification facilities has led the LNG industry to consider alternative transfer methods. In particular, the use of LNG hoses has surfaced as a viable solution to what at times can be a harsher and more complicated transfer environment offshore. At the same time a similar emergence of the use of cryogenic hoses for land to sea bunkering of vessels has been observed.

LNG hoses are currently offered by a number of suppliers in various sizes and configurations. In general there are two types of cryogenic hoses

available to the market: corrugated stainless steel hose and composite polymer fabric and wire mesh hose. Corrugated stainless steel hose have had a long service history in LNG service. The vast majority of the service has been on small diameter (less than 6 inches) applications for activities such as road transport loadings. Composite hoses represent a more recent advancement and their use and application is growing.

6.3.2 Overland Transfer Equipment

Road trailers, ISO containers and rail cars all are expected to have similar operational characteristics. The vast experience loading LNG road trailers should be used as a starting point for the design and operation of loading facilities for ISO containers and rail cars. In 2009, GIIGNL published its “Study of the Overland Transport of LNG”. This industry-wide study on the transport of LNG by road truck included the results of an extensive industry questionnaire solicitation and addressed many equipment related issues. From this effort and a continued monitoring by GIIGNL’s TSG on overland transportation of LNG, the following general equipment observations can be made:

- ✓ **Fixed arms vs. hoses** - Flexible loading arms (hoses) are the most prevalent design. However, hard arms are gaining in popularity and the corresponding percentage of hard arms in use worldwide is increasing.
- ✓ **Loading Bay Safety Systems** - Facilities do not rely on any one safety system in and around the loading bays. Multiple systems are employed by all companies responding to the questionnaire.
- ✓ **Security** - Multiple security precautions have been put in place for the arrival, processing and departure of LNG vehicles to loading sites.

While the LNG loading/offloading operations of Rail cars and ISO containers are similar to that for road trailers important operational differences remain. For example, the use of ISO-containers will require additional mechanical handling (e.g. lifting the containers onto/from the designated transportation vehicle and stacking in terminals and ships decks). This may well increase the operational resources requirements.

6.3.3 Transfer Equipment Challenges and Opportunities



6. Equipment Utilized in the LNG Process Chain

For the Retail LNG distribution chain, smaller volumes of product are being transported than in the typical large scale chain. However, there exist many operational challenges regardless of the volumes transferred. Transfer operations present one of the greatest safety risks to personnel. The risk of leakage and the overfilling of containers need to be addressed through technology, procedures and the appropriate application of available equipment.

New entrants into the Retail LNG market should look to experienced LNG operators, such as the members of GIIGNL, for guidance in selecting appropriate technologies and developing robust systems and procedures. These entrants have the opportunity to learn from decades of experience and take advantage of the wide dissemination of knowledge (i.e. through white papers, industry groups, safety studies, standards, checklist, etc.) by the incumbent LNG operators.

- ✓ **Cryogenic Hoses** – The use of hoses must be robust and reliable while maintaining the operational safety levels that the current loading systems provide. Mechanical damage and fatigue related issues must be addressed in each application. Ergonomics and the proper support for the weight of the

hoses employed must be carefully considered.

- ✓ **ESD and QCDC System Adjustments** - An emergency decoupling system is usually in place to break away in the event of over-extension to prevent rupture of fixed arms. This system is typically activated by position sensors which detect if the vessel is moving outside of the normal operating range of the arms. Initially an ESD will activate to stop cargo transfer before a complete disconnection if excessive movement continues. This disconnect system must still be effective if the terminal is loading a small vessel, so some modification to the position sensors and control systems may be required.
- ✓ **ESD and QCDC System for Hoses** – To achieve similar levels of safety and operational performance as fixed arms, the addition of Emergency release systems and quick connect disconnect couplers to flexible cryogenic hose systems should be considered where practical.
- ✓ **Piping** - Check valves in the loading lines of Import Vessels would need to be converted or removed in order to allow LNG to flow from tank to vessel and vapor to flow from

vessel to tank. Some modification may also be required to the knock-out drum on the jetty.

- ✓ **Surge** - When valves in the loading lines are closed suddenly, for instance during an emergency shutdown, a surge event could occur. The effect of surge during a reloading operation should be examined to ensure that the existing design and surge alleviation measures are adequate.

The transfer of LNG to other means of transportation such as road trailers and rail cars may face similar challenges.

One way around some of these issues in the marine space is the use of purpose-built adaptable vessels. Coral Methane, the world's first small-scale combined LNG/LPG/LEG, was specially designed by Anthony Veder to be compatible with both large scale and small scale terminals. This was achieved by equipping the vessel with both high and low level manifolds and flexible hoses allowing for the safe transfer of LNG over a wide range of operational conditions. If such vessels are readily available in the market, modification to the terminal itself could be relatively minor.

An alternative to specialized and adaptable

6. Equipment Utilized in the LNG Process Chain

vessels capable of transferring LNG over a wide range of facilities is the construction of a purpose-built jetty for smaller vessel, as at the Zeebrugge terminal in Belgium. There a recently completed second jetty has been designed to take vessels as small as 3,500 m³. Similarly, in Rotterdam at the Gate LNG Terminal, facilities for small scale vessels in the range of 1,000 m³ to 40,000 m³ are being completed. Services are planned to commence in mid-2016.

6.4 Transportation Equipment

Once LNG has been transferred to vessels, trailers, rail cars, etc. the product will leave the confines of the LNG production and/or storage facilities. Once outside of these facilities, the transportation of LNG relies on multiple levels of protection to ensure public safety. The design of the equipment, materials of construction, crash worthiness, resistance to fire, corrosion prevention, pressure management, compliance to codes and regulations (MC-388, ADR, etc.), labeling along with training and emergency response plans have all been successfully implemented in an effort to safeguard the transportation of LNG.

The development of retail LNG with smaller and scattered end users requires a more extensive and flexible transportation network. The main transportation methods for retail LNG include:

- ✓ Marine Transportation – Using LNG bunker barge or Small LNG Carrier. It is expected that SS LNG bunker barge and SS LNG carrier will be required to follow the same regulatory requirements, and design and operational codes and standards as for traditional LNG carriers.
- ✓ Overland Transportation - Using Road Trailer, ISO or Rail. Road trailer is the most commonly used transportation means for Retail LNG. For example, it has been widely used for refilling storage tanks at refueling stations, or direct refueling to marine users at the port as a fast track option for bunkering projects. Inter-modal Transportation via Iso-Containers could be used to transport LNG via a combination of road trailer, rail and container ship, thus offering a high degree of flexibility. This transportation method is mostly considered for remote island users, where a single mean of transportation is not feasible.

6.4.1 Marine Transportation

Equipment

Traditionally LNG is transported via large scale LNG carriers between export and import terminals. Marine transportation of LNG has an excellent safety record. GIIGNL estimates that over 75,000 shipments have been made from base load export terminals to onshore and off-shore receiving terminals worldwide [25]. A fleet of over 400 LNG vessels employing robust designs are currently in operations.

Traditional LNG vessels must comply with all relevant local and international regulatory requirements, including those of the International Maritime Organization (IMO), International Gas Carriers Code (IGC) and US Coast Guard (USCG), as well as any additional requirements imposed by the government administration of the country of registry.

As part of GIIGNL's LNG informational series of papers on LNG, "LNG Information Paper No. 3 – LNG Ships" was published which provides additional details on the safety, general design and operation, training and security of LNG vessels in the conventional LNG trade. Many of these equipment details are applicable to the marine transportation of LNG at the Retail scale.

6. Equipment Utilized in the LNG Process Chain

6.4.2 Overland Transportation Equipment

LNG road trailers have a long and safe record of operation. Advancements in “anti-roll” technology and vehicle monitoring systems are increasing the safety of LNG trailers. Designs of trailers are “pushing” the center of gravity lower and lower. At the same time, “active” systems which monitor vehicle conditions (speed, turning radius, etc.) and can apply braking or other measures are being developed and implemented. Cryogenic trailers are also decreasing in weight and increasing in total capacity. This trend is expected to continue. Advancements in insulation technologies have also been improving, providing better performance and operational flexibility. The use of single walled, foam insulated trailers is still prevalent in some areas. It is recommended that new entrants into the Retail LNG market understand the differences in design of these trailers to that of the vacuum insulated designs. For market participants currently involved in the transportation of LNG in such trailers, it is suggested that appropriate risk analysis be performed while instituting suitable mitigation strategies to reduce the associated risk.

Cryogenic ISO containers are widely available. Many vendors have optimized these containers for transporting LNG worldwide by rail, sea or road. Users are also employing the containers for onsite LNG storage. The vacuum- insulated ISO containers are designed for thermal performance, ease of operation and safety.

Most designs employ ISO tunnels for gooseneck chassis applications. The containers can also be enhanced with pressure build circuits allowing them to be used in LNG vaporization applications.

ISO containers have been used to transport LNG by rail. Large scale transportation of LNG by rail utilizing “tanker cars” has not been done to date. Tanker cars employed in the ethylene market would represent a decent example of what the design of LNG tanker cars could look like. Additionally, some parallels can be drawn between LNG tanker cars and LNG tender cars that have successfully completed test trials.

Currently there are two basic types of tender cars, a tank car style and an isotainer style. The tank car style units are typical cylindrical cryogenic tanks permanently mounted on a railroad car chassis. There have been only 4 made in the US to date (circa 1980’s/1990’s).

They still exist today with two of the tender cars undergoing trials today while another one of the cars was loaned to Canadian National for their 2013 trials. The cars feature internal pumps or gravity/pressure fed systems. All four cars have recently been refurbished.

An isotainer style car was recently developed by Westport and it features a standard cryogenic isotainer dropped into a common railroad well car and positively fastened down. Westport made 4-5 of these style cars as production units however they have yet to be approved for use by the US Federal Rail Administration or Transport Canada so the future of this technology is in question.

6.4.3 Transportation Challenges and Opportunities

In general, the Retail LNG market is well supplied with technology and equipment borne from decades of LNG activity. As discussed in preceding sections, the optimization of existing technologies represents a significant opportunity for the Retail market. Potentially opening the way for safer, more efficient and cost effective offerings.



6. Equipment Utilized in the LNG Process Chain

In the marine space the fleet of smaller vessels is expanding as the LNG market focuses on increasing flexibility, new distribution channels and new markets. It is therefore increasingly reasonable to expect that suitably small LNG carriers would be available if required. However, GIIGNL members, and operators of LNG Import Terminals, will be challenged to evaluate the compatibility of the vessels with their existing large scale jetties and piping systems. Significant technical challenges may be present including, but not limited to, the following:

- ✓ **Vessel Mooring** - Typically, a conventional LNG import jetty is designed to cater for LNG tankers ranging from about 70,000 to 175,000 m³ in capacity and consequently a number of modifications (e.g. to mooring hooks, bollards, gangways, fenders, etc.) will be required if the terminal is to be used for the loading of smaller vessels (approximately 1,000 – 10,000 m³ in size).
- ✓ **Loading Arm Envelope** - The existing unloading arms at an LNG import terminal are articulated arms which are designed for safe unloading from vessel to tank. Smaller vessels may not be tall enough to be reached by the loading arms, and as such they may need to be extended by the

addition of a flexible hose or replaced with longer ones.

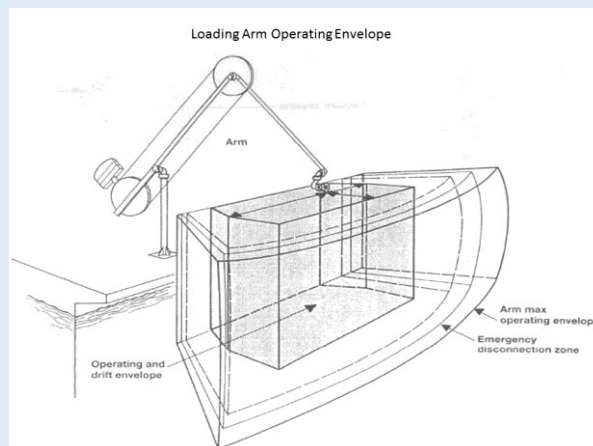


Figure 17 - Marine Loading Arm Operating Envelope
(Source: Marine Insight [64])

For ISO-Containers, there are additional risks associated with mechanical handling (e.g. lifting and stacking) that need to be managed.

6.5 End Users Equipment

The following sections briefly address some of the key equipment and technologies used by end users in the Retail LNG market. In all applications, consideration should be given to the use of such safety equipment as breakaway couplers, grounding, overpressure protection, protection from mechanical damage, vehicle

collision, gas detectors, remote isolation and emergency shutdown systems. In many regions the codes and standards governing the End User facilities will include many of the components listed above. However, all market participants should consider employing such measures regardless of the regulatory regime in place.

6.5.1. Equipment for Marine Use

Environmental and economic drivers are important for the adaptation of LNG as a fuel. Equally important is the technology required to safely and effectively capture the opportunities presented. In the case of LNG as a fuel for marine use, there exists substantial operator experience with gas engines and the LNG components necessary. “All of the technologies needed to use LNG as a marine fuel are proven and commercially available including dual fuel and pure gas engines in power ranges that meet the needs of many types of costal and deep see vessels.” [14]

LNG fueled marine vessels currently have three engine technologies available to meet their operational requirements:

- ✓ Spark ignited lean burn
- ✓ Dual fuel diesel pilot ignition with low

6. Equipment Utilized in the LNG Process Chain

pressure fuel injection

- ✓ High Pressure Direct Injection (HPDI) Dual fuel diesel pilot ignition with high pressure fuel injection

Spark ignited engines operate exclusively on natural gas. Engines dedicated to natural gas have the advantage of being 'optimized', ensuring maximum efficiency and optimum emissions results. These engines operate on the thermodynamic Otto cycle, which consists of two isentropic (reversible adiabatic) phases interspersed between two constant-volume phases. They also require a spark plug to ignite the fuel/air mixture within the combustion chamber. At present, lean burn spark ignited engines are being offered by the likes of Rolls-Royce Marine/Bergen, Mitsubishi and Hyundai.

Dual fuel diesel pilot ignited marine engines, in two stroke or four stroke configuration are based on the same OTTO cycle. These engines use natural gas together with a second fuel source such as distillate or heavy fuel oil. A lean premixed air-gas mixture is provided by the turbocharger and admitted in the combustion chamber of each cylinder by a controlled gas injection valve; the mixture is ignited by a small amount of pilot diesel fuel. The injection valve of the gas and pilot fuel can be combined or

separate according to the vendors design.

In Dual Fuel engines the combustion must be closely controlled to prevent knocking and misfiring. The overall air-fuel ratio is controlled by a wastegate valve, which lets some of the exhaust gases bypass the turbine of the turbocharger. This ensures that the overall air-fuel ratio has the correct value independent of changing ambient conditions such as the ambient temperature. The quantity and timing of the injected pilot fuel are adjusted individually together with the cylinder-specific and overall air-fuel ratio to keep every cylinder at the correct operating point and within the operating window between the knock and misfire limits.

Manufactures of Dual fuel engines with diesel pilots include Wartsila, MAN, Caterpillar/MAK, ABC Diesel and Electro Motive Diesel.

A proprietary technology developed by Westport Innovations (Canada), High Pressure Direct Injection (HPDI) technology involves the injection of both diesel and gas at high pressure directly into the combustion chamber at the end of the compression stroke. Like a dual-fuel engine, HPDI relies on diesel for combustion to occur. The system differs from the dual-fuel system in the manner in which the fuels are

mixed and, in comparison to an equivalent diesel engine, is reported to deliver the same high power and torque with same or higher efficiency.

A diesel substitution rate of over 90% is achieved. The two fuels are not pre-mixed with the intake air before they enter the combustion chamber so there is no risk of engine knock and therefore, no need to lower the compression ratio and peak torque output. As compared to diesel fuel, directly injected natural gas burns with a lower adiabatic flame temperature and has a low propensity to the formation of carbon particles and therefore offers inherent nitrous oxide (NOx) and particulate matter (PM) emissions benefits that provide more product engineering flexibility to allow powertrain designers to increase potential performance and customer value.

To date, the onboard storage of LNG has been predominantly within Type C tanks. Type C tanks are normally spherical or cylindrical pressure vessels having design pressures higher than 2 barg. The cylindrical vessels may be vertically or horizontally mounted. Both "integrated" (within the vessels structure, below deck) and "deck" mounted tanks have been used and are being considered. Focused attention is



6. Equipment Utilized in the LNG Process Chain

being paid to the location of any storage tanks. The requirements for “tank rooms” for any integrated solutions include the need for spill containment/secondary barriers to mitigate the effects of any potential leak or release.

Due to the inherently lower energy density of LNG, and the corresponding increase in storage volumes needed to provide the equivalent fuel capacities, space considerations have become important for owners and operators. Additionally, the physical location of storage tanks on board vessels, effects of that location on bunkering operations, the relationship to accommodations, ability to perform simultaneous operations (i.e. bunkering and cargo/passenger transfer at the same time), etc need to receive due consideration.

“Boil-off” of the LNG will continue to be an operational challenge that owners and operators of LNG fueled vessels will face. Even in the well-insulated storage tanks designed for LNG service the gradual egress of heat, resulting in boil-off, is inevitable. In Type C tanks the gradual increase in pressure due to this boiloff can be managed to a point, but ultimately either the use of the boil off as fuel, re-liquefaction, or venting will be required.

6.5.2. Equipment for Over the Road Use

Similar engine technologies presented above in 6.5.1. Equipment for Marine Use is available for over the road applications. In addition to the information provided above, the following is intended to provide further details of the

equipment available for over the road applications.

Spark Ignited natural gas engines are well suited to medium-duty applications such as rigid and single trailers, waste collection vehicles cement delivery, urban delivery vehicles and buses.

Dual fuel and HPDI engines are well matched to

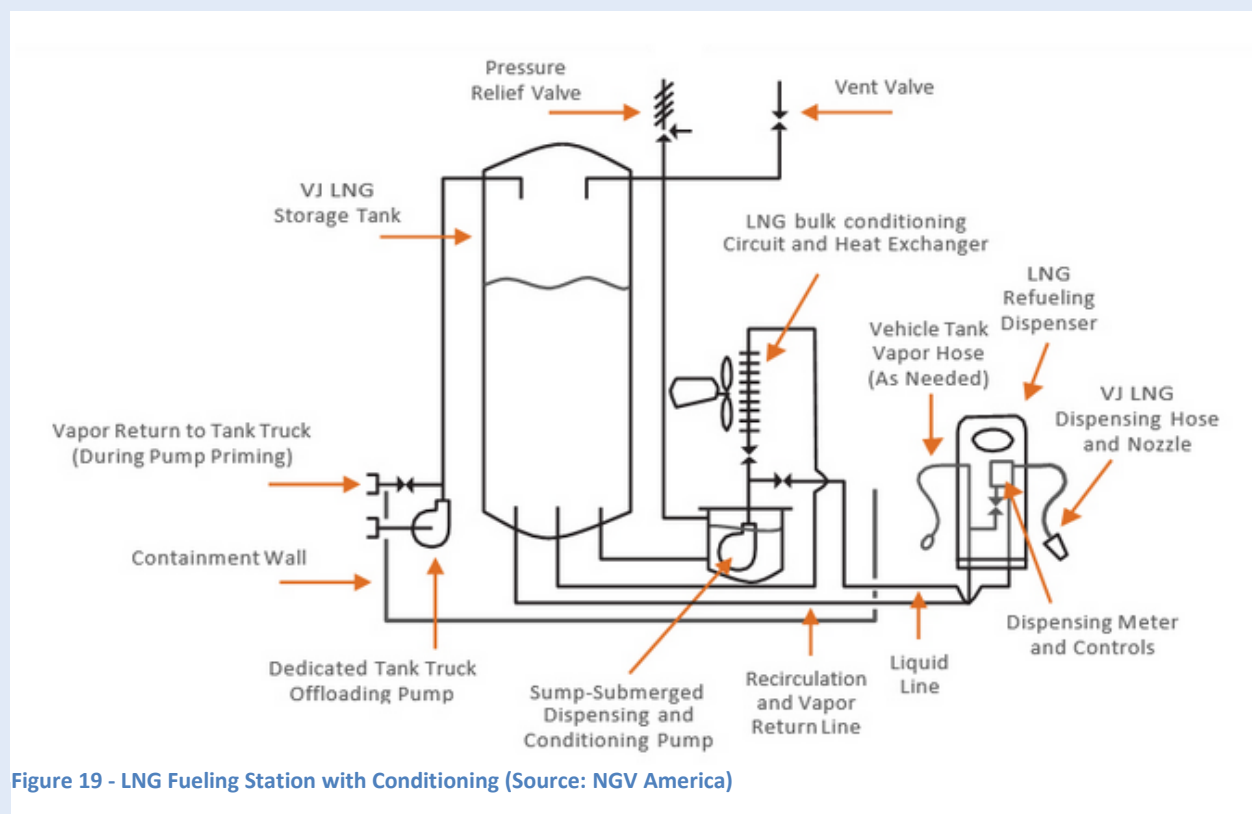


Figure 19 - LNG Fueling Station with Conditioning (Source: NGV America)

6. Equipment Utilized in the LNG Process Chain

heavy and severe-duty applications. These users require large amounts of fuel and the onboard storage of LNG can provide increased energy storage vs. CNG. Dual fuel engines are very flexible allowing a conventional diesel engine to operate simultaneously on diesel and natural gas, and revert to 100% diesel operation if LNG is not available. The engines have proven to be capable of retaining the efficiency, torque and power characteristics of compression ignition diesel engines, while consuming LNG as a supplemental fuel. Dual fuel and HPDI engines are being employed in many medium and heavy duty applications such as regional and bulk haulers as well as multiple trailer applications.

The over the road applications utilizing LNG as a fuel are usually supplied via a LNG Fueling Station. Some successfully applications have utilized “mobile” LNG refueling, however the basic design and capabilities of both the traditional LNG fueling station and the mobile solutions are essentially the same.

LNG fueling stations will generally be supplied via an over the road LNG trailer. At the fueling site the LNG is transferred from the LNG trailer into the fueling stations storage system. As with other Retail LNG applications the predominant fueling station storage tank design is that of the

pressurized bullet tank. Standardization of fittings has not been fully adopted across the entire LNG market. However, it has been observed that the industry is trending in that direction.

LNG from storage is usually pumped via a dispensing pump to the LNG dispenser. LNG is either directly pumped and dispensed into the on board LNG storage tanks of the end user, or it is “conditioned” in a process that raises the temperature of the LNG prior to being sent to the dispenser.

In applications in which there are planned CNG users, either solely or in conjunction with the LNG users, the addition of CNG capabilities has been added to LNG fueling stations. This variation, commonly referred to as LCNG, used LNG to make CNG using LNG pumps in lieu of the traditional gas compression normally utilized at most CNG fueling stations. “LCNG stations use a separate pump to pump LNG to an ambient air vaporizer, where the LNG is warmed to approximately 40 °F and becomes a gas. The gas is then odorized and goes through a priority fill system, fuel storage vessels, a sequential system, temperature compensation system, and dispensed into the vehicle” [26].

An example of how an emerging market such as Retail LNG faces challenges with regard to the application of vendor technologies and equipment can be illustrated by the current state of LNG dispensing nozzles and onboard storage tank receptacles. Currently there three main types of nozzles and receptacles being utilized in the transfer of LNG from LNG fueling stations to over the road end users. The vendors JC Carter, Parker Kodiak and Macrotech all offer both nozzles and receptacles. However, within the various combinations of nozzles and receptacles there exist some compatibility issues that need to be recognized.

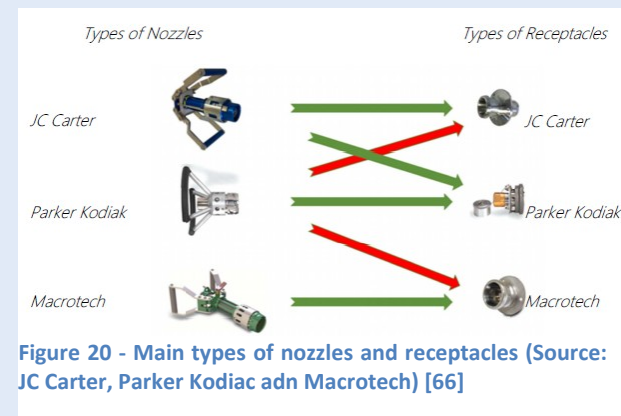


Figure 20 - Main types of nozzles and receptacles (Source: JC Carter, Parker Kodiak and Macrotech) [66]

6.5.3 Equipment for Rail Use

Interest in the use of LNG for fuel for locomotives is most apparent today in North

6. Equipment Utilized in the LNG Process Chain

America where essentially all of the freight movement is fueled by liquid petroleum fuels. It is estimated that the major railroads in the United States alone consume more than 3.5 billion gallons of diesel per year.

“Continued growth in domestic natural gas production, along with substantially lower natural gas spot prices compared to crude oil, is reshaping the U.S. energy economy and attracting considerable interest in the potential for fueling freight locomotives with liquefied natural gas (LNG). While there is significant appeal for major U.S. railroads to use LNG as a fuel for locomotives because of its potentially favorable economics compared with diesel fuel, there are also key uncertainties as to whether, and to what extent, the railroads can take advantage of this relatively cheap and abundant fuel” [27].

However, even with positive drivers for the adoption of LNG in the rail space, there exist significant challenges. The cost of the infrastructure build out, upgrading of maintenance facilities, training of staff and more intensive logistical issues are but a few of the obstacles. On the regulatory side, LNG rail cargos currently are not permitted without a waiver from the Federal Railroad Administration

(FRA) under Federal Emergency Management Agency (FEMA) rules. However, the development of standard LNG tenders and regulations is underway, with issues related to safety, crashworthiness, and environmental impact, including methane leakage, under consideration [28].

Since this segment is essentially still in its infancy, limited information is available on the equipment utilized. However, both historical and recent trails have provided insights into what the future equipment of this segment may look like.

Currently the two largest locomotive builders, Electro-Motive Diesel (EMD) and GE Transportation, are prototyping engine kits that would enable their existing engine offerings to support dual-fuel operations. In essence these modifications would be similar in nature to what has been looked at for the marine, E&P and mining markets.

Association of American Railroads (AAR) has established a Technical Advisory Group (TAG) which is trying to assist the Federal Railroad Administration (FRA) in developing a tender-car standard. Formed in late 2012, the TAG is reviewing equipment and establishing design

standards for fuel tenders, hoses, piping and other tender-locomotive interface connections, as well as addressing safety systems related to LNG-powered locomotives, interoperability and interchangeability [29].

In Canada the major rail roads have been testing conversion kits using both Dual Fuel and HPDI engines. Brazil has seen the conversion of a small number of locomotives to dual fuel and there have been reports of Russia, India and Australia investigating the use of natural gas for rail.

6.5.4 Equipment for Exploration and Production (drilling and pressure pumping) Use

In North America, operators of drilling rigs and pressure pumping spreads have been examining ways to decrease onsite liquid petroleum fuel consumption by replacing it with natural gas. The use of untreated “pad gas” has presented technical and commercial challenges, in many cases, due to the need to process the gas to some degree before it can be utilized locally. In other cases the gas is “dry” enough that its use presents an excellent opportunity to reduce operating cost and avoid the logistical challenges



6. Equipment Utilized in the LNG Process Chain

of delivering fuel to the site. CNG has also faced challenges, mainly due to the volume requirements and the logistical challenges of delivering the required volumes to remote sites in CNG form.

LNG has had success in fueling the drilling rigs (both dual-fuel and dedicated), generator sets, and the pressure pumping equipment used for hydrofracturing. The demands of this market segment, high volume, high horsepower and the rapid ramping of loads, have proven to be an ideal test bed for not only the engines that are fueling on natural gas, but the LNG systems employed to deliver the fuel.

Similar to the equipment utilized in stationary applications described below in the Commercial and Industrial section, the equipment utilized for these applications is very similar to the equipment employed within LNG Import Terminals. However, since drilling rigs and pressuring pumping equipment are required to move from site to site, the Retail LNG equipment associated with this segment has to a large extent been designed to be mobile.

To date the onsite storage of LNG has been achieved with LNG trailers and ISO containers. LNG regasification equipment has usually been

skid or trailer mounted and comprised of fired water bath heater type or electric vaporizers.

6.5.5 Equipment for Commercial and Industrial Use

Commercial and Industrial end users in remote areas, islands, or in locations not well served by traditional pipeline supply due to geography or cost of pipeline infrastructure, have begun to look to LNG as a replacement fuel. The desire to cut emissions, and in some locations, access a lower priced fuel has led to the development of many LNG supplied fuel supply facilities.

Operators of LNG Import terminals will find many similarities in the equipment and operations of C&I installations. The basic process flow of LNG through the C&I installations closely resembles the process flow of Import Terminals. Transfer from a mobile transportation asset, storage on site, regasification equipment to meet demand and associated utilities and controls make up the basics of the C&I installations.

C&I facilities will usually have an equipment package which is used to offload LNG from transport trailers into LNG storage vessels. The

offload package will have as many offload connections needed to match the volume/logistical requirements of the end user. Offload pump(s) are usually controlled locally with a start/stop control panel.

If storage requirements are such that multiple storage tanks are required, the LNG storage vessel fill line will be manifold to the tanks with an automatic or manual filling selection process. LNG storage vessels will normally include a pressure building coil that will allow for the continuous withdrawal of LNG for use during the offloading operation.

Storage vessels are usually pressurized code vessels in either vertical or horizontal orientation. Capacities typically range from 5,000 to 400,000 liters with typical service pressures between 5.0 to 17.0 barg. Most designs utilize connections and piping which allow for top or bottom filling of the vessel. With advancements in insulation technologies the thermal performance of these vessels has improved dramatically in recent years. The Natural Evaporation Rate (NER), which is the percent of liquid boiled off per day given a full tank at atmospheric pressure, is the common metric for measuring thermal performance and is now 0.07-0.15% for modern vessels [30].



6. Equipment Utilized in the LNG Process Chain

In the majority of installations, the liquid withdrawal from storage is accomplished by means of pressure. The pressurized vessels are allowed to operate at a pressure suitable for the end user requirements. If higher pressures are required, simple centrifugal ground pumps or in-tank pumps are installed. For installations with multiple tanks the withdraw lines will be manifold to the regasification section of the process.

A common trend in small Retail LNG applications is the use of ambient vaporizers coupled with a smaller electric or gas fired trim heater. While the merits of such applications in locations like the Dominican Republic or the south of Spain are evident, successful applications have been proven in colder clients such as the northeastern United States and Scandinavia. To account for icing issues, switching banks of vaporizers are employed. A simple control system is included

to automate the vaporizer switching system's functionality. The use of more traditional "fired" vaporizers such as water bath vaporizers and fully electric vaporizers have also seen success.

In many instances where the regasified fuel is being sent to a process area or into buildings a wick-style odorant system will be included just prior to the regulating manifold. Dual stream regulation manifold designed for required flow with low temperature shut-down capability, a flow meter and all of the required utilities will usually complete the process scheme.

All equipment, including the LNG transfer area, would normally be contained within impoundment areas. In some cases vapor fencing would be employed around the periphery of the installation to help mitigate vapor propagation within the facility or offsite. A detailed fire detection/protection evaluation, by a licensed and qualified fire protection engineer identifying the appropriate type, quantity and physical siting of equipment necessary for the detection and control of fires, leaks and spills of LNG, is required by code in many cases and is recommended.



Figure 21 - C&I Industrial Applications (Source: R.F. White)

6. Equipment Utilized in the LNG Process Chain

6.5.6 Equipment for Other End Users

Large mining trucks, trucks with greater than 100 tons of capacity, can consume between 150,000 and 400,000 gallons of diesel fuel annually and over two billion gallons of diesel fuel are consumed annually by the top ten mining companies. There are over 28,000 of these trucks in service around the world today, and there may be up to 40 trucks at a single mine. Most of these trucks operate in confined return-to-base rotation, making the logistics very favorable for the mining industry to convert their trucks to LNG [31].

A limited number of conversions to existing mine haul trucks have been completed to date. Vendors such as Caterpillar, Westport and GFS Corp are offering engine solutions to the market.

In Russia a Tupolev Tu-155 airplane was tested running on LNG to demonstrate the feasibility of using cryogenic fuels for aviation. As recently as 2012 major manufacturers such as Boeing introduced aviation concepts utilizing LNG.



7. Availability of LNG Supply

There are currently 110 Export Terminals and 110 import terminals active globally [25]. These facilities represent a great potential for supplying the emerging Retail LNG market. Generally, these facilities have substantial LNG storage, robust marine facilities and are usually located in close proximity to marine transportation hubs. As such, the economics of any particular LNG project may be significantly improved if the capabilities of the existing infrastructure can be utilized efficiently. Operators of Export and Import terminals could transport LNG to end-users via, over the road trailers, ISO containers, rail cars, barges, small marine LNG vessels or other methods.

For end users located too far from existing Export and Import Terminals to effectively take advantage of their capabilities, and in countries with sufficient gas reserves, regional liquefaction facilities may provide economically viable supply solutions. Such facilities may be “merchant” in nature or tied to local natural gas distribution infrastructure in the form of satellite LNG peaking facilities that store LNG for use during peak demand periods.

7.1 LNG Export Terminals

It is apparent that LNG produced at large scale export Terminals can provide an excellent source for Retail LNG. The economies of scale employed in these facilities allow for the efficient and cost effective liquefaction of LNG. The most basic supply scenario would involve the loading of LNG onto conventional LNG carriers, which would in turn transport the LNG to market where break-bulk operations could distribute the LNG to Retail applications. LNG supplied today from LNG Import Terminals would fall into this type of Retail LNG supply arrangement and is discussed in more detail in following sections of the Handbook.

Another potential supply arrangement would include the modification of a conventional LNG export facility so that the export facility can transfer lesser volumes of LNG directly onto small LNG vessels, over the road trailers, rail cars, ISO containers, etc. Taking further, the direct bunkering of LNG vessels at LNG export facilities is feasible. However, such plans would face many challenges. Jetty facilities, including ship to shore compatibility issues, and berthing rights may present limitations for the access to the terminal from Retail LNG customers. The physical location and battery limits may present challenges for the addition of over land transfer

equipment within the site and the access to the site by customers.

As new export facilities are being planned and constructed there appears to be recognition of the potential of supplying LNG to Retail markets by the project developers. In the US alone there are at least two LNG export projects that have openly indicated that they have plans to incorporate small scale capabilities into their facilities. In Lake Charles, Louisiana the proposed Magnolia LNG Export Terminal has included loading of bunkering barges or ships as part of their design. In Cameron Parish, Louisiana Cheniere Energy has an agreement in principle to supply LNG from its Sabine Pass LNG Export Terminal, to LNG America. LNG America intends to distribute LNG in the greater Gulf Coast region and potentially export LNG to other regions using vessels with a planned 3,000 m³ capacity [32].

7.2 LNG Import Terminals

Due to the market drivers described in 5.1 Market Drivers of this Handbook, there is increasing interest in LNG as a transportation fuel and for small-scale use for heating, process needs and electricity generation in rural “off-



7. Availability of LNG Supply

grid” areas. This usage of LNG requires LNG supply infrastructure, which provides existing regasification terminals an opportunity to potentially play a significant role. As mentioned above one means of doing this is to utilize the LNG import terminal for break-bulk operations. This may include the addition of equipment and systems or the modification of the terminal for the loading of small-scale LNG vessels which transport LNG to satellite terminals, bunkering facilities or directly to other vessels as marine fuel. Another option is to add or modify a regasification Terminal to facilitate the transportation of LNG via road trailer.

In countries such as Japan, Spain, Turkey and the United States there exists LNG import terminals which already have robust existing capabilities and infrastructure needed for break bulk operations. Smaller facilities are also located throughout the Baltic. Existing facilities in places like the United Kingdom, Belgium and Netherlands are actively enhancing the capabilities to support such Retail activities.

7.3 Small-mid size merchant liquefaction facilities

In countries with readily available natural gas

Illustrative Example – Fluxys LNG Terminal, Zeebrugge Belgium

The Fluxys regasification terminal in Zeebrugge (Belgium) is an open access regulated facility with a throughput capacity of 6.7 mt/y and operational since 1987. Originally designed as an LNG import facility, the terminal is currently diversifying into a hub for small-scale LNG in order to unlock the potential of LNG as fuel for ships and long-haulage trucks.

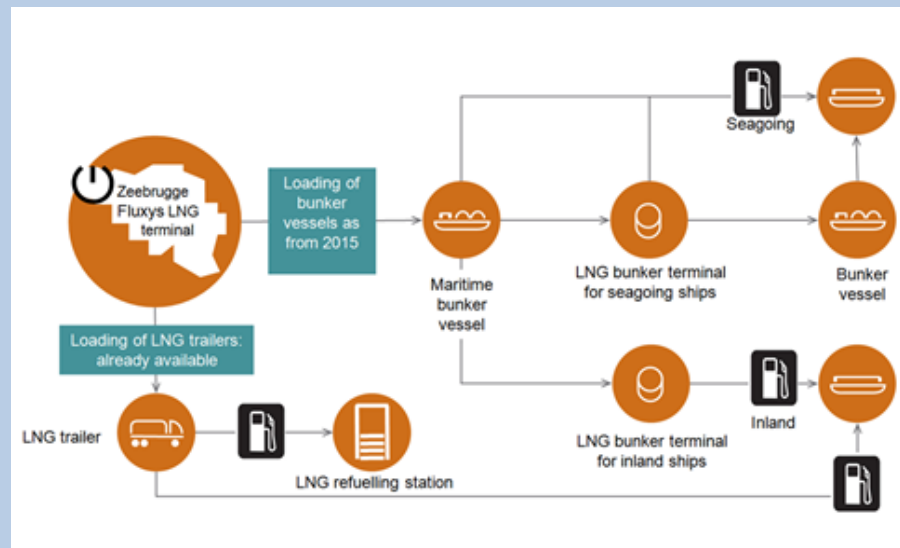
Ship and truck loading services - Since 2008, the Zeebrugge LNG terminal offers ship loading services to accommodate demand from terminal users to valorise Zeebrugge delivered LNG in other markets. 100 LNG ship have been loaded to date, among which the Coral Methane with a LNG volume of 7,500 m³. With the introduction in 2010 of LNG truck loading services the Zeebrugge terminal started pioneering along the small-scale LNG trail. The truck loading has a capacity of 4,000 loadings per year.

LNG for ships - Currently, LNG-powered inland navigation vessels are supplied via tanker trucks that take on LNG at the LNG terminal in Zeebrugge (truck-to-ship bunkering).

To kick-start market uptake for LNG as shipping a multifunctional 2nd jetty is being built at the Zeebrugge terminal for; Unloading and loading of standard LNG ships with a capacity up to 220 000 m³ of LNG, Loading of small LNG ships including bunker vessels with a capacity from 2,000 m³ of LNG, Ship-to-ship transfers.

LNG for long-haul trucks - Fluxys is actively involved in developing LNG refueling infrastructure for trucks. Its first filling station in Veurne is operational since October 2014. The LNG is supplied from the Zeebrugge terminal.

Zeebrugge Fluxys LNG Terminal's Retail LNG distribution capabilities



7. Availability of LNG Supply

resources, small-mid size merchant facilities have provided regionalized LNG supply to the emerging end users of LNG as a fuel. These facilities simplify logistics by placing supply as close as possible to the consumers. LNG as a fuel is inherently more costly to transport than the alternative petroleum based products due to energy density and the cryogenic nature of the product. Because of these transportation costs, the location of supply and use is of critical importance. By balancing complexity, operating efficiency, and capital cost these merchant facilities are designed to be capable of delivering a competitively priced alternative fuel to end users.

Small-mid scale liquefaction plants are expected to be used when they can offer more economically viable solutions than their world scale counterparts or in cases in which the commercial aspects of obtaining small volumes of LNG from larger facilities becomes too onerous. Distance between end users and supply points could obviously also help justify smaller units strategically located closer to the consumers.

Additionally these smaller merchant facilities can monetize gas reserves that are not large enough to justify the building of traditional LNG export

facilities. Small traditional gas reserves as well as applications such as flare gas capturing have justified development of these small-mid size facilities.

7.4 Other Supply Sources

Peak shaving facilities may represent another potential supply source for LNG to the Retail LNG market. These facilities store LNG that they receive from production facilities or that they produce themselves onsite. The LNG is regasified during periods of high demand. In the US alone there are more than 120 of these facilities and an estimated 260 globally [33]. Predominantly associated with Local Distribution Companies (LDC), these Peak shaving facilities usually have service requirements that must be met before any LNG can be available to markets other than the ratepayers of the utility. However, in some markets as pipeline networks have expanded and the utilization of the Peak shaving assets has decreased, these facilities have demonstrated that, similar to LNG import terminals, they are a viable supply solution for the Retail Market.

Bio-methane plants can clean, purify and liquefy landfill gas and other waste methane streams

for use in the Retail Market. Gas made in anaerobic digesters or land fill sites is typically 65% methane and 35% carbon dioxide, with contaminants in the form of water, hydrogen sulphide and siloxanes. Through processing the contaminants and the majority of the carbon dioxide is removed. The resulting Bio-methane is typically 97% methane, 2% carbon dioxide and 1% oxygen. In California, bio-methane produced from landfill waste creates both CNG and LNG for use as a gasoline or diesel substitute to reduce emissions in an array of vehicles: light-duty vehicles, transit buses, solid waste trucks, and off road heavy-duty equipment [34].



8. Aspects of LNG Supply

Since 1964, LNG production, export, import and distribution has followed a process that has resulted in an excellent safety record by any measure. GIIGNL as a representative body of the LNG industry is committed to the communication of experience and knowledge throughout the process chain. Understanding the hazards of LNG, managing the associated risk and maintaining operational protocols and operator knowledge are imperative for all members of the LNG industry.

As the supply of LNG to Retail market grows, it will be imperative that the level of care and custody that the historical LNG industry has provided be maintained by all Retail LNG market participants. Industry knowledge, and the collective lessons learned of the broader LNG industry, need to be shared with new entries.

As with the practical issues and requirements provided herein on equipment utilized in Retail LNG, the following can be used to help guide and facilitate a skilled operator team to work out suitable solutions for Retail LNG applications. No particular procedure is implied to be suitable for any specific purpose in this Handbook. Readers should ensure that the basic issues described for safety, security, staffing, equipment siting, operations, commercial,

quality and regulatory concerns are understood and considered when planning for and operating their specific applications.

The following illustrative examples of the measures taken in the existing LNG market, and recommended for the emerging Retail LNG market, are largely based upon the supply of LNG via road transport. However, where appropriate, reference is made to additional types of supply transportation including, but not limited to, ISO containers, marine vessels and rail cars.

8.1 Safety

The most important safety requirement for the industry is to safely process, store, and transport LNG. There are a number of guidance documents and requirements which are intended to assure the safe operation of onshore and offshore LNG facilities, personnel and vessels. Section 4 of this Handbook provides an overview of many of these. Strict adherence to government regulations, codes, and standards has led to the LNG industry's exemplary safety record. Sharing best practices through non-profit trade organizations has also served to strengthen the safety culture of the

entire industry.

Within each application developed for the Retail LNG market, it will be imperative that skilled operators review plans and identified risk associated with the operations. While each application will exhibit their own unique characteristics, there are some general common issues requiring due consideration.

The release of product to the atmosphere in various points along the process chain is generally considered the greatest risk involved with Retail LNG. Leakage can be due to mechanical damage, human error, faulty equipment and controls, and improper connections during transfer operations. The cryogenic nature of the fuel, its propensity to "boil-off", and lack of distinctive odor also presents various challenges in terms of safety.

8.1.1. Assessment of Risk

The development of solutions for supplying LNG to the Retail LNG market should be conducted with high focus on safety. Risk to personnel and property must be closely examined. Such risk analysis normally comprises the following effort:

- ✓ **Study Basis** - definition of study basis;



8. Aspects of LNG Supply

- ✓ **Risk Assessment** - performing risk assessment of the operation;
- ✓ **Siting** - establishing safety distances for the operation;
- ✓ **Verification** – confirmation that design is in accordance with code requirements, recognized standards and that agreed safeguards are implemented.

Once a common understanding of the definition of the study is obtained amongst all stakeholders, an assessment of risk to personnel and environment shall be carried out as a part of the development and new infrastructure or modification of existing infrastructure. Guidance documents such as ISO 31010, ISO 17776, and ISO 16901 are recommended to be followed.

The first step of the risk assessment shall be to identify what can go wrong with the operations. Determine what in the system can fail. What human or control errors can happen? What are the issues that can arise during operations? This can be considered the identification of the hazards.

Once hazards are identified, an assessment of the effect of the hazards shall be made. An evaluation of what will happen should a hazard

be presented should be done. Typically this would be termed a consequence and impact assessment.

The final two steps should be assessing the likelihood of the hazard and how often it is expected to happen (frequency assessment), and then deciding if the risk is tolerable, and if not, identify risk reducing measures.

GIINGL members and operators of LNG import and export terminals are ideally suited to participate in risk analyses for Retail LNG applications. Their knowledge and experience will be beneficial to any team analyzing the safety of new infrastructure. Regardless of the inclusion of existing LNG operators, any team evaluating Retail LNG solutions should be well rounded, comprised of individuals with pertinent knowledge and capable of objective and independent assessment.

8.1.1. Safety Systems Employed

The following describes the operational safeguards which the industry implements as standard practices to detect, control and minimize potential effects from a release of LNG. The safety of LNG worldwide is the result of high industry standards, effective regulations, and a

fervent industry commitment to rigorous risk management. Regardless of the type of LNG facility, multiple layers of protection should be considered to minimize the likelihood of an LNG release.

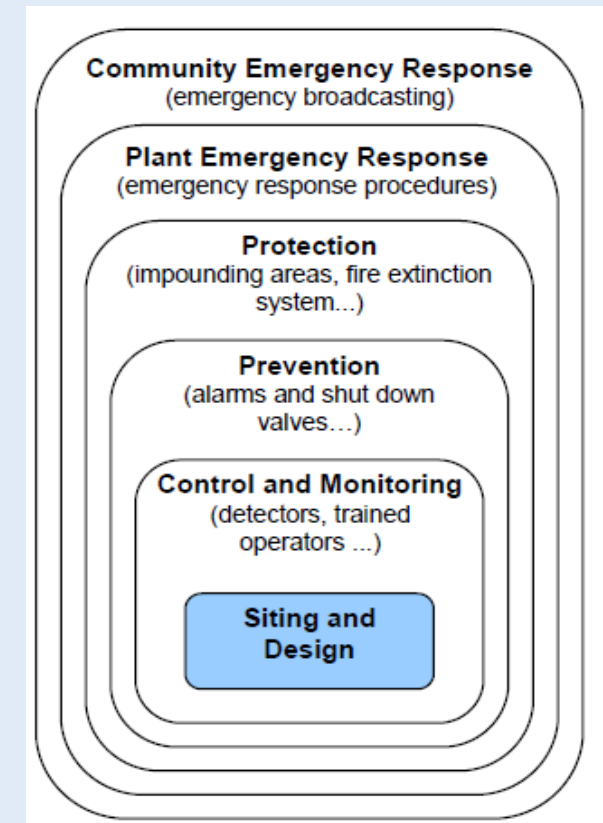


Figure 22 - Layers of protective layers to prevent escalation of an LNG leak into a pool fire (Source: Bureau Veritas)

8. Aspects of LNG Supply

Typical layers of protection for transfer operations implemented in modern LNG terminals begin, in a sense, with the Siting and Design of the terminal. The next layer reflects the Control and Monitoring features (including, for example, detectors and trained operators). Prevention components include alarms, shut-down valves, etc. Protection is provided by elements such as impounding areas and fire extinction systems. Company management of an incident is provided by implementing the Plant Emergency Response procedures. In addition, Community Emergency Response begins with notification about the leak or other incident, which activates governmental oversight, mobilizes additional response resources to reinforce the facility's response, and thereby protects the public and adjacent properties.

Examples of standard practices established in the existing LNG industry which should be considered for Retail LNG applications to prevent leaks during transfers and their escalation include the following:

- ✓ Compliance with known and proven codes and standards for designing and siting new facilities;

- ✓ Siting new facilities a safe distance from adjacent populations based on risk assessments;
- ✓ Construction of special materials and inclusion of systems designed to safely insulate and store LNG at temperatures of -162 °C (-259 °F);
- ✓ Various codes and standards for maintenance and inspection of equipment in LNG service;
- ✓ Overpressure protection (pressure controllers and relief valves);
- ✓ Leakage detection and spill control through temperature probes;
- ✓ Ignition source control;
- ✓ Fire zoning;
- ✓ Emergency depressurizing;
- ✓ Passive fire protection, e.g., fireproofing, fire resistant barriers and coatings; and
- ✓ Active fire protection.

In LNG export and import terminals, the majority of LNG transfer systems for transport trailers and marine vessels are equipped with LNG vapor

leak detection, fire detection, low temperature leak detection and associated safety shutdown systems that shut down pumping operations and close valves to isolate the transfer lines. The shutdown systems can be actuated by LNG terminal personnel, locally or from the control room. In most cases, these systems also respond automatically to any detection of LNG in the atmosphere, this serves to limit the amount of LNG that would be released if a leak occurred during the unloading/loading process.

The robust systems described are appropriate for the scale and level of activity at the large scale facilities. As noted, the application of similar systems to Retail LNG applications is possible, and could be considered a “starting point” to the design of safety systems, for these smaller installations. However, a careful evaluation as to the appropriateness of many of the systems and the level of detection and automated controlled reaction to hazards that may be present at Retail LNG installations should be performed by qualified personnel.

LNG road transport trailers and LNG ISO containers are designed with similar technology that has been used to transport other cryogenic materials, such as liquid oxygen, nitrogen or hydrogen, so the design has already been



8. Aspects of LNG Supply

extensively used in industry and it has an excellent safety record. Emerging applications like LNG rail cars are undergoing extensive review, but likewise, have used the vast experience in services such as liquid ethylene as a starting point for their design and construction. [35]

LNG road transport trailers have an excellent safety record. In fact, the robust, double-walled, insulated construction of the LNG trucks'/trailers' storage tanks make an LNG leak extremely unlikely. The use of appropriate materials is key to ensure that the tanks can both withstand very low temperatures in order to avoid brittle fracture, and are strong enough to stay intact during a crash of the vehicle. In addition, the storage tank materials are designed such that corrosion will not occur.

This safety record is attributable to continuously improving trailer technology, trailer safety equipment, comprehensive safety procedures, training, equipment maintenance, and effective administration and knowledge sharing

GIIGNL also advocates for the standardization of connections for the various pieces of equipment in the Retail LNG process chain. Lessons from the industrial gases market should be utilized

where appropriate. Standardization of connections can reduce the chance of human error while having the benefit of streamlining operations.

“Storage and Handling of LNG may expose personnel to contact with very low temperature product. Plant equipment that can pose and occupational risk due to low temperature should be adequately identified and protected to reduce accidental contact with personnel. Training should be provided to educate workers regarding the hazards of contact with cold surfaces (e.g. cold burns), and personal protective equipment (PPE) (e.g. gloves, insulated clothing) should be provided as necessary [36].

8.1.2.Procedures

Well-written procedures help improve the quality of work within an organization, help reduce the number of errors and omissions, and help new people perform any complex tasks quickly and effectively. They are written by experienced but relevant team members for each section; i.e. operational, safety and instrumentation, etc. There will be specific procedures for specific disciplines. These may interact e.g. an instrument trip system

procedure may incorporate operational input to create the conditions to test the trip system.

Procedures are reviewed on a time basis (normally up to 3 years) or when updates, modifications, investigation actions or actions from audits occur. Each procedure will have its author and up to 2 different reviewers before management approval is given to the document being released. An electronic copy of this procedure will normally be installed into a site Document Management System. This system enables traceability and accountability for all procedures maintaining a reference point for audits and these become the controlled document. Updated paper copies will be placed in the control room. All procedures that have been produced or updated will be issued to all team members, read and signed for as a record of compliance.

Introducing a new operation into an existing LNG terminal, such as bunkering small vessels, or loading road trailers, may require that the control systems and operating procedures be updated and operators to be re-trained such that transfer operations can be conducted in a controlled and safe manner. The existing facility HAZOP is not likely to include consideration of potential Retail operations, as this is not



8. Aspects of LNG Supply

typically part of the original design intent for import or export terminals. As such, a new or supplementary HAZOP would need to be completed.

Being prepared for any emergency is an essential activity for LNG operations. A set of preparedness activities conducted before an incident helps assure that any incidents that do occur are well managed and mitigated. To be most effective, preparedness activities are conducted in a sequence, where the results of one activity leads into another, with the end result being that overall preparedness is constantly improving. This is referred to as the Preparedness Cycle. Preparedness is achieved and maintained through a continuous cycle of planning, organizing, training, equipping,



Figure 23 - Preparedness Cycle (Source: US FEMA)

exercising, evaluating, and taking corrective action. Ongoing preparedness efforts among all those involved in emergency management and incident response activities ensure coordination during times of crisis.

A good emergency response plan helps assure that responders have optimal control over an incident. Beginning to plan response actions at the time of an incident is an extra but avoidable challenge. For this reason, LNG facilities prepare and maintain emergency response plans which identify potential credible incident scenarios and then develop specific actions to mitigate the consequences of such incidents. Such plans and procedures will be critical for Retail LNG applications.

The regulations of countries, including the US and Europe, and companies, specify the content of these plans. For example, emergency response plans for import terminals, which in the US are required by FERC and must be approved before the terminal even begins operations, must include scalable procedures for responding to:

- ✓ emergencies within the LNG terminal;
- ✓ emergencies that could affect the public

near an LNG terminal;

- ✓ emergencies that could affect the public along an LNG vessel transit route;
- ✓ methods for notifying agencies and the public; and
- ✓ training and exercises using the plan.

It is important to involve all response stakeholders (including adjacent facilities) in the planning process to develop the plan. The facility emergency response plan should be prepared in consultation with appropriate local and national governmental agency representatives, including first responder representatives. The valuable benefit of a plan is the planning process of working through incident management issues.

Another key component of emergency planning is the training of all emergency responders, which incorporates coordination, communication, drills and exercises. Hazards and mitigation scenarios are identified and used to develop responses and role assignments. Simulated emergencies, both table-top and full-scale, are used to validate the effectiveness and efficiency of both individual responders and responding organizations. Field exercises provide an opportunity to practice hands-on skills and cultivate expertise.

8. Aspects of LNG Supply

Participating in such training and exercises helps assure that the emergency response plan will be well understood by the organizations with responsibilities during an incident and that they are ready to respond effectively in the unlikely event of an emergency.

8.1.3. Training

“Addressing training needs for seafarers as well as for a range of other stakeholders is crucial to ensuring the safe operation of LNG-fuelled vessels and related operations. In this regard, it is vital to [leverage the lessons learned](#) from the [existing LNG industry](#) to ensure that LNG’s safety record is maintained.” [14] The authors of this quote were specifically addressing the marine sector but obvious parallels can be drawn to each of the other sectors in the emerging Retail LNG market.

Training is based on organized activities aimed at imparting information and/or instruction to improve the recipient’s performance to help them to attain a required level of knowledge or skill. Depending on the activity whether it be a standalone process or a part of a process an individual will be trained and passed out on that particular activity. The use of training modules for each section of knowledge required including

the testing of the recipient has proven effective. Upon completion of testing, the site management can sign off that the individual is able to undertake the activity that was the subject of the training. Company competencies are produced and all training records kept up to date.

Operations and maintenance personnel in existing LNG facilities are required to be trained, both initially and periodically thereafter in:

- ✓ the hazards of LNG;
- ✓ the hazards of operation and maintenance activities;
- ✓ how to recognize breaches of security and execute security procedures;
- ✓ understanding the potential causes, types, sizes and predictable consequences of fires and knowing and following fire prevention procedures;
- ✓ how to perform their assigned functions during both normal operations and emergencies; and
- ✓ how to provide first aid.

Verification of compliance with these

requirements is usually performed by each national dedicated Authority. An evaluation of each Retail LNG application should, at a minimum, use the above along with local regulations as a starting point for the development of site and system specific training program.

In respect of transfer operations for LNG trailers or small marine vessels at LNG import terminals, the training could potentially be specifically be focused on loading operations and emergency procedures. This would not require full shift technician operations training, i.e. a standalone activity. All employees should be trained on emergency activities as part of the introduction to the site. Refreshers training for all activities should be entered into individual’s personal training plans and should be reviewed when there is a change to the operation or an incident has occurred.

All drivers of LNG trailers and crews of marine vessels are skilled operators in their own right and know their equipment and that of the end user. It is recommended that each LNG supply facility provide the same training, if appropriate including hands on or “on the job” training with terminal personnel, to each driver on the operational aspects of LNG supply



8. Aspects of LNG Supply

(transfer/loading). The driver should be accompanied until he is approved. No driver would be allowed to attend site to load until he has demonstrated competency and on the trailer/vessel approval list.

8.1.3. Verification and Inspections

As the Retail LNG market continues to emerge, the method and frequency of verification and inspection by government authorities will be clarified. Government agencies routinely inspect existing large scale LNG facilities and vessels to verify that safety measures have been correctly applied and maintained. Inspections vary among countries or regions. For example:

- ✓ **European area:** The Safety Management System, required by the European Directive Seveso III and implemented by the owner, includes internal control loops for every safety activity. In addition, some verifications are made by oversight agencies and inspections are performed by Local Authorities. The frequency of these inspections is variable for each facility. The Seveso III consent must be renewed every 3 years.
- ✓ **US area:** Safety activities fall under the

jurisdiction of OSHA (Occupational Health and Safety Administration), Pipeline and Hazardous Materials Safety Administration (PHMSA) of the US Department of Transportation, or Department of Homeland Security/US Coast Guard. Each agency will verify the safety activities that fall under its jurisdiction through inspections. The inspection rate is chosen by the responsible agency and will vary by facility. The Federal Energy Regulatory Commission (FERC) requires quarterly reports from the import terminal operators and typically also makes annual inspections.

- ✓ **Other areas:** Similar procedures are implemented by government agencies in Asia and wherever a new LNG terminal is constructed. For example in Japan, the Ministry of International, Trade and Industry (MITI) prescribes inspection frequencies.

8.2 Security Concerns

LNG terminals include a range of layered and multiply-redundant security measures and systems. The specific measures and systems are selected from a wide range of possibilities by risk assessment, usually in conjunction with government security organizations and are

deployed according to national alertness criteria. By their very nature, Retail LNG applications may be “closer” to the public and detailed evaluation of the appropriateness of security measures to employee should be completed by the operator and local governmental officials.

With regards to transfer operations at existing LNG facilities, security concerns start and stop at the supply facilities security gate. In most cases, customers calling on the site are given a common “code of conduct” procedure to adhere too. All trailers have strict entry checks and these are done by trained security staff with all driver credentials as well as trailer integrity checked prior to entry to site. Based upon recent work by GIIGNL, it is estimated that close to 90% of the terminals request information on incoming trailers prior to the trailers arrival at the loading/unloading facility. [37]

Once on site, all trailer movements on site are controlled with speed limits and barriers in place. Terminal operations monitor the movement and activity of the trailers through CCTV or onsite personnel. In some cases, terminal personnel accompany the trailers from the time they enter the gate to the time the trailers exist the supply facility.

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When loading trailers the operator must consider other vehicle movements across site and other process control conditions; e.g. venting, which the operations department will control. Where there is a multiple bay configuration onsite staggered time slots between bays can take place to limit the chance of two trailers moving within site at the same time.

8.3 Staffing Requirements

As the Retail LNG market continues to emerge and grow it is expected to tap into the existing sources of knowledge within the LNG industry. A 2014 report by the Canadian Natural Gas Vehicle Alliance identified 5 distinct potential pools of experience which may be invaluable to the emerging marine sector: the LNG carrier industry, operators of existing LNG fueled vessels, Classification societies, OEM's and shore-based LNG facility operators. The former being noted for "decades of experience in handling and processing LNG" and having "intimate knowledge of the skills and training required to ensure safe and reliable operations". [14]

Each facility will determine its staffing

requirements solely on production activities and loading bay usage. All terminal staff should all be trained and competent on loading or loading of LNG vessels. Although in some cases, the trailer drivers or ship masters are trained in loading their own equipment, they should always be accompanied or monitored throughout the loading process by a qualified (gone through a formal training program approved and signed off by the manager) LNG technician. Permanently employed dedicated loading technicians could also be engaged depending on the number of trailers or vessels loaded per day. Depending upon the infrastructure of the facility and its utilization, timed slots for loading may become important to reduce waiting times of the customer.

The vast majority of end user drivers or operational personnel decant their LNG loads at their respective customers without assistance from LNG supply terminal staff. This is true for other cryogenic carriers throughout the industry so staffing further down the retail chain, while still very important, should not pose significant issues.

8.4 Equipment Siting

"The determination of where to locate an LNG facility whether it is storage only or includes liquefaction are quite complex and will likely have a major impact on the ultimate cost of the project" [32]. It is important that evaluations are made to determine the impact to the well-being of the users of the facility and the neighboring area. Demonstrations should be made that clearly indicate that the proposed Retail LNG facilities have an acceptable level of risk to facility personnel and the public.

The proper siting of Retail LNG equipment and facilities should start with the application of good engineering practices, a determination of regulatory jurisdiction and the use of relevant design standards. Preliminary siting and feasibility study can then be used to determine whether a particular parcel of land is appropriate for the proposed project. As described previously for large scale export and import terminals the applicable design codes are generally clear and any new process addition to an existing LNG facility would normally be governed by the same guidelines and procedures as the facilities original construction.

For instance in the UK, on a Control of Major Accident Hazards (COMAH) site (in the UK COMAH governs as part of the Seveso directive),



8. Aspects of LNG Supply

HAZOP's would be required for any new installation. A new trailer loading bay would be sited as close to the tie in point (either from a standalone tank or from a common recirculation line between tanks) as possible to reduce expenditure on stainless steel piping other materials and equipment. The site would preferably be located away from the main process control plant area with good road access to and from site. Where possible, and for a large trailer loading facility, a separate access to the bays may be appropriate. Areas designated for offload of the LNG would depend on what's in the surrounding area and buffer zones would be installed to safeguard this from any public hazards. Buffer zones are extremely important areas both within a terminal and outside at customer locations and control of these zones is essential for a smooth operation.

For Retail LNG facilities outside of the well-established regulatory framework of large LNG facilities, the appropriate requirements and approved models for siting are often less clearly defined. These requirements can also vary greatly based upon size and from region to region dependent largely upon who has jurisdiction over the proposed facility. It is suggested that at minimum the references

mentioned in 4.1 Existing Codes/Regulations, Standards/Guidelines and Industry Organizations of this handbook be reviewed and taken into consideration.

For illustrative purposes, the following siting analysis steps have been provided. The steps listed have only been provided for context and should not be considered as a complete, and all-encompassing, list of the required diligence items required for the proper siting of Retail LNG facilities.

- ✓ Develop conceptual general arrangement, equipment list and process flow diagram for an installation which provides the desired operational flexibility and objectives.
- ✓ Based upon the conceptual layout perform some screening evaluation of potential vapor dispersion distances identifying potential problem areas that may need mitigation.
- ✓ If necessary rearrange the general arrangement and evaluate the effectiveness of any mitigation measures.
- ✓ Perform vapor dispersion modeling per the applicable requirements and taking into account the physical properties of the site

and atmospheric conditions.

- ✓ Perform thermal radiation modeling to determine thermal radiation levels at different distances.
- ✓ Consider performing other hazard modeling to address such potential risk as Deflagration, BLEVE² or RPT³ effects.
- ✓ Considering the results of all modeling adjust general arrangement for the proposed facilities.

In parallel to the development of a general arrangement of the proposed facilities based upon vapor and thermal dispersion, consideration should be given to the following:

- ✓ Natural Hazards including severe or extreme

² BLEVE is a phenomenon that can happen when a pressurized liquid gas tank is subjected to a sustained external heat source such as a neighboring fire degrading the structural integrity of the tank. The degradation of the integrity can lead to a sudden rupture of the tank, and in the event of such a rupture the boiling liquid simultaneously expands and ignites causing a powerful explosion and thermal dose. BLEVE can only occur with pressurized tanks, it can't happen to tanks with atmospheric pressure which is what is used for all large scale LNG terminals and ships [65].

³ RPT is a phenomenon that may occur when LNG is released onto water. The water will cause quick heat transfer into the LNG making it a superheated liquid. Once evaporations starts the LNG will evaporate instantly and cause a pressure pulse. RPT is a flameless explosion that can be compared with the cracking noises (small explosions) when heating cooking oil with small amounts of water inside. Significant damages caused by the phenomenon are not expected and have not been observed [65].



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weather, site metocean⁴ conditions, hurricanes and typhoons, tsunamis, earthquakes and effects of climate change.

- ✓ Site access including consideration to any resulting traffic issues.
- ✓ Site security including hazards, threats and vulnerabilities.
- ✓ Adjacent activities and the potential for imposing on neighbors, or neighbors imposing on the LNG facility, unacceptable limitations.

8.5 Transfer Operations

The properties, characteristics and behavior of LNG differ significantly from conventional transportation fuels such as gasoline, diesel, heavy fuel oils and distillate fuels, marine diesel oil (MDO) or marine gas oil (MGO). Because of these differences it is crucial that all LNG transfer operations are performed with diligence and due attention is paid to prevent leakage, the spillage of liquid or vapor. Therefore, it is necessary that for every type of LNG transfer operation each system or component is

adequately designed and has appropriate safety, operational, inspection and emergency procedures that can be followed by trained personnel.

Additional attention should be paid to such issues as pressure relief requirements which would need to be calculated to confirm whether the existing pressure relief system is appropriately sized for the new operation involved with the Retail LNG process chain.

8.5.1. Marine Vessels Transfer Operations

The Society of International Gas Tanker and Terminal Operators (SIGTTO) have recently published guidelines for bunkering from tanker vessels or barges. These guidelines cover ship-to-ship LNG transfer between LNG carriers at anchor, alongside a jetty or while under way. SIGTTO's initiative has now been taken a stage further with creation of Society for Gas as a Marine Fuel (SGMF) as a formal Non-governmental Organization (NGO) which aims to promote the use of natural gas as a safe and environmentally friendly marine fuel while retaining a safety level equivalent to that of the large scale LNG transport industry.

The majority of GIIGNL members are also members of SIGTTO and both organizations have the common goal of sharing knowledge and experience in support of the maintenance of the LNG fields' excellent safety record. As SIGTTO points out, a safety record that "stems from adherence to rigorous codes and standards for the design, construction and operation of both the vessels employed, and the marine terminals where they load and discharge their cargo. The codes, standards and industry guidelines were written by drawing on the expertise of the people engaged in the industry and they have been continuously updated and reviewed in light of experience" [38].

The use of SIGTTO's guidelines as a starting point for the development of the Terminal operating procedures covering potential transfer operations from LNG Import Terminals to vessels employed in Retail LNG trade is suggested. These guidelines should be supplemented with local knowledge of the LNG facilities, port conditions, regulatory requirements, etc. The development of marine terminal operating procedures by staff qualified and knowledgeable of the risk associated with the operations is imperative.

As with existing procedures within LNG Import

⁴ Meteorological and Oceanographic conditions (Metocean) include data on wind, wave, current and tidal conditions.

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Terminal, the aspects of marine transfer operations should be defined and frequently reviewed for accuracy to ensure they are in line with industry developments. Best practices include manning levels and crew qualifications, structural condition checks by independent surveyors prior to docking, pollution prevention, mooring and anchoring equipment, engine room and steering gear checks, communications, navigational standards and crew safety management is suggested. All these appraisals would be carried out prior to a vessel's being loaded or off loaded. It is expected that Terminal staffing would include a marine superintendent, jetty engineer and shift technician who would liaise with the vessel's captain and loading/offloading engineers. Once developed, the terminal operating procedures must be adhered to for all vessels that birth at a LNG terminal.

Hazards unique to the transfer of LNG over water also need to be taken into account. A spill of LNG on water evaporates about five times faster than on land because of the higher heat transfer rates associated with the water and a tendency for the water not to completely freeze. The high heat capacity and the circulation of the water at the surface usually inhibits significant

ice formation. Depending upon the quantity spilled and the conditions, LNG has a tendency to spread and form a pool on the water surface because it is insoluble. This pool of LNG will evaporate and create a vapor cloud which expands, begins to dilute, and moves with the ambient wind conditions. The actual size, rate of expansion, movement of a vapor cloud depends upon incident-specific conditions. A first approximation is that the size of the LNG pool will increase until the vapor generation rate equals the LNG release rate. If ignition sources are not present when the part of the vapor cloud that is within flammable limits (5-15% natural gas in air), then no fire will occur.

Some LNG spills on water may have a Rapid Phase Transition (RPT). This is essentially a flameless overpressure caused by the very high transient rates of heat transfer from the water to the LNG. This causes the LNG to change from the liquid to the gas phase so quickly that a rapidly expanding vapor cloud is generated. The cloud can expand so quickly that a sonic boom and localized overpressure is created.

The RPT "explosion" phenomenon for LNG on water has been observed in a number of situations and has been studied extensively in both laboratory and large-scale tests. While this

phenomenon is spectacular to observe at large-scale tests, the actual energy release is modest. An RPT is a very unpredictable phenomenon and the exact circumstances of its formation remain unclear. The temperature of the water and the actual composition of the LNG are important factors in predicting whether or not an RPT will take place. Work has also been performed to examine the impact of an RPT on the LNG vessel and pier structure. Measured overpressures are insufficient to cause more than minor damage either to the vessel or pier.

As ABS recently described in its informative report on bunkering gas-fueled marine vessels in North America; "There are multiple options for bunkering LNG on to vessels, depending on how

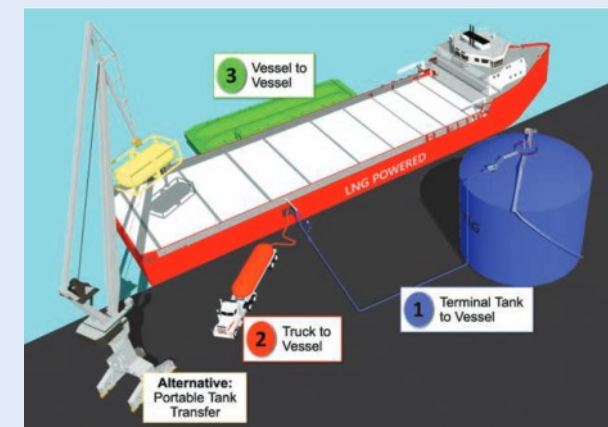


Figure 24 - Standard LNG Bunkering Options (Source: ABS)

8. Aspects of LNG Supply

the LNG sourced and whether or not a bulk storage tank or bunkering vessel is present at the bunkering location” [32].

GIIGNL agrees with ABS, DNV and others, that there are basically four standard means in which to transfer LNG onto marine vessels. They are as follows:

- ✓ **Shore to Vessel** – Marine vessels arrive at terminals specifically designed to transfer LNG to the vessel. LNG is transferred from storage through cryogenic pipelines and either hoses or fixed marine loading arms are used to connect to the vessel. LNG can be transferred using pressure, when the LNG is stored in pressurized vessels or cryogenic pumps when LNG is stored in atmospheric flat bottom tanks.
- ✓ **Truck to Vessel** – Providing a great deal of flexibility, the bunkering of marine vessels directly from LNG trailers which have been moved to prearranged transfer locations has proven viable. Typically, cryogenic hoses are used in the transfer process. With limited LNG volumes available per trailer, logistics become challenging as the fuel supply needs of the marine vessel increase.
- ✓ **Vessel to Vessel** – LNG transfer from one

vessel to another can be utilized in many ways and can add operational flexibility to the LNG suppliers. LNG transfer can take within the port or at anchorages and are most similar to the experience that the end users have today. Due consideration, and mitigation of, risk such as vessel movement, sea state, vessel traffic, etc. are needed.

- ✓ **Portable Tank Transfer** – Depending upon the fuel supply needs of the end user and vessel design, the transfer of portable fuel storage tanks to marine vessels is feasible. ISO type containers can be driven or lifted on and off the marine vessel as needed. Concerns associated with connection points, external impacts during transfer operations and impacts to vessel to design exist.

8.5.2.Over the Road Trailer Transfer Operations

As addressed in 8.1.1. Safety Systems Employed, 8.1.2. Procedures and 8.1.3. Training the

transfer of LNG to over the road trailers relies on multiple safety layers to manage LNG risk.

The road trailer loading facility will have two possible types of connections to a road trailer; these are either hard arms or flexible hoses. As is similar with most other cryogenic trailers, connections to the road trailer will be at the rear or center of the vessels. Other types of equipment found in the loading facility may include, fire and gas detection, custody transfer, ESD and other safety systems. Additionally, loading facilities will normally employ LNG spill

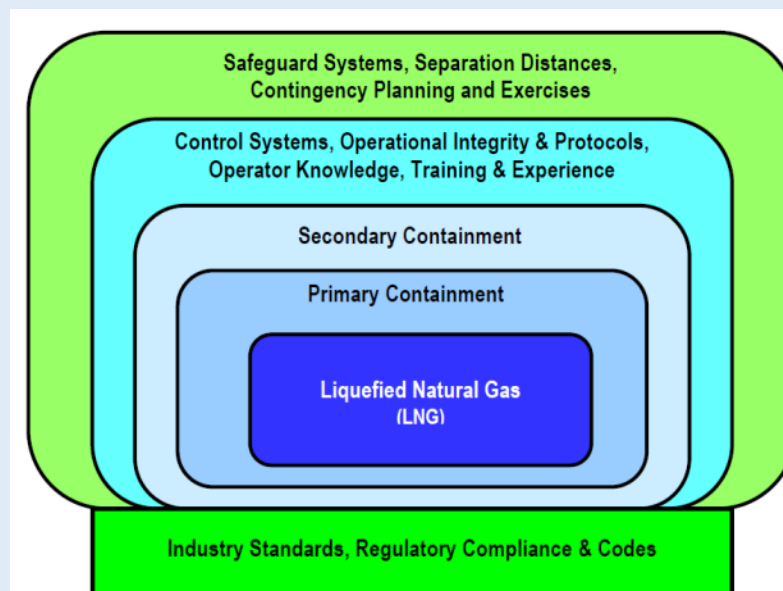


Figure 25 - Multiple Safety Layers to Manage LNG Risk (Source: GIIGNL)

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containment for the loading areas.

Road trailers are designed and built to international standards and hazardous liquid regulations apply. For example in Europe the ADR or Agreement covering the international carriage of Dangerous goods by Road is the prime regulation that applies. Each trailer has its own unique identification number and is regular checked for its integrity. Through this identification number a loading or unloading facility will recognize the trailer and usually have all its maximum fill details incorporated into the fill system procedure which will help to ensure over filling will not occur.

There are numerous safety systems within these trailers such as relief valves and emergency shut off valves. It is important to be mindful of the compatibility of trailers and their safety systems such as set points of pressure relief valves and the facilities which load them, and that they discharge into. The majority of cryogenic trailers have brake interlocks and drive away prevention/protection features, which would automatically shut down a filling system. All road trailers will have formal product identification and emergency contact details on its vessel as well as engineering identification plate stating maximum working pressures etc.

Upon completion of transfer operations documentation (paper or electronic) should be exchanged between the parties to meet regulatory requirements and accurately reflect the particulars of the transfer (quantity, quality, etc.).

8.5.3. ISO Containers Transfer Operations

These vessels are physically similar to the above road trailers with the notable exception of having a steel frame surround so they can be transported onto a rail carrier, over the road trailer, or marine vessel when necessary. These vessels will normally have their pipe work connections on their side as opposed to the ends. Great care should be given to the loading and unloading of ISO containers and recognition of significant differences that may exist between ISOs and over the road trailers. The lack of many of the safety enhancements such as emergency shut off valves, brake interlocks, etc, may not be present in every application.

As with over the road trailers the condition of the vessel must be verified prior to commencing transfer operations. This not only includes checking the physical condition of the vessel, but

the temperature and pressure conditions within the vessel. Cool down operations should be performed if necessary and additional verification that there are exist no traces of oxygen, water vapor, CO₂, or other impurities should be made.

8.5.4. Rail Cars Transfer Operations

Although the transfer of LNG to rail cars has historical experience going back to the 1970's the level of activity has been very limited and meaningful conclusions as to significant differences between loading Rail Cars and loading over the road trailers or ISO containers cannot be made at this time. As this market segment expands, GIIGNL intends to keep a close eye on the developments and solicit operational feedback from its members when appropriate.

8.5.5. Other

As other means of transporting LNG are introduced to the Retail LNG industry, or the broader LNG industry, GIIGNL will solicit operational feedback from its members and evaluate the effectiveness of the new

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technologies.

8.6 Commercial Considerations of LNG Supply

“The opportunity to use natural gas as a transportation fuel is significant, but substantial commitments to the infrastructure and vehicle investments will be necessary to markedly reduce the role of petroleum fuels” [23]. For those countries without significant gas reserves (or severely underdeveloped domestic gas reserves), the Retail LNG commercial value chain will necessarily be a derivative of that country’s LNG import capability. For those countries with domestic natural gas, existing and developing small-scale LNG production will likely compete with larger import facilities, with market share being dictated by geographic considerations directly related to the cost of transporting LNG by truck or vessel and price differentials between the cost of domestic gas and the global market for LNG.

The traditional LNG value chain was developed under a very conservative model with several key requirements:

- ✓ The targeted quantity of LNG production is

significant – anywhere from 1 MTPA to 20 MTPA (or more);

- ✓ Long-term (often 20 year or greater tenor) contracts with large, credit worthy end users or LNG portfolio players;
- ✓ Long-term and dependable sources of gas supply with exploration & production programs undertaken by multinational investor owned oil & gas upstream players or successful national oil companies;
- ✓ Proven technology for liquefaction at the large scale, with well capitalized engineering, procurement and construction firms of international stature handling project execution; and,
- ✓ Large commitments for vessel construction.

The Retail LNG process chain is developing under very different circumstances. Key differences from the traditional LNG value chain are:

- ✓ LNG is substituting for traditional fuels (e.g. heavy fuel oil, diesel) in much smaller applications – whereas the customer for a traditional facility may be a national gas transmission system or a large power plant, the Retail LNG customer may be much smaller;

- ✓ The credit quality of the average Retail LNG customer is questionable by comparison to the traditional customer – many are poorly capitalized with thin operating margins;
- ✓ Customers in the Retail LNG market are generally unwilling to contract for supply on a long-term basis – this is primarily due to their current fuel market which is ubiquitous, credit-accommodating, and very short-term in nature;
- ✓ Customers must make significant new investments in equipment – new LNG storage and vaporization, new fueling equipment new engines, new trucks, new vessels/boats or new locomotives in order to consume natural gas. Customers are looking for payback periods from one to five years with upside after that;
- ✓ Customers who do not necessarily have experience with LNG in either operation or commercial transactions.

- ✓ Many participants, less “centralized” market

With respect to the use of existing LNG import or export terminals for the supply of LNG to the Retail LNG market, in addition to the challenges presented due to the differences in the process chains of traditional and Retail LNG markets,



8. Aspects of LNG Supply

there exist some commercial issues that will need due attention. GIIGNL - with support from its Commercial Study Group - intends to expand this Retail LNG Handbook in the near future in order to address in more detail both the commercial considerations, and the aspects of the use of LNG by the end customers.

8.7 Measurement of LNG Supply

“As an extension of the traditional distribution chain for LNG a new market of professional consumers is developing with LNG as transport fuel. In this case there is no commonly agreed measurement practice and the metrological framework is not yet in place. This will be a showstopper for the roll-out of the LNG as transport fuel because laws will be enforcing protection of (professional) consumers. For small scale LNG the legal metrology framework will lay down requirements on traceability to national standards and will define maximum permissible measurement errors. This is not the case for large scale LNG where the industrial players are assumed to take care of their own business interests” [39]. Efforts are underway to develop the metrological framework with joint

research projects like the European Metrology Research Program’s “Metrology for LNG 2” attempting to “improve and develop the metrology for LNG custody transfer measurements leading to smaller measurement uncertainties, reduction of financial risks of transactions and more transparency in the trade of LNG” [40].

In the traditional logistic chain (large scale operations), measurement of LNG is usually based on static level measurement, in combination with online gas composition analysis. This method allows for the quantity of LNG transferred to be determined on an energy basis. The LNG industry has developed robust measurement techniques and operational procedures to ensure that measurement uncertainty is kept to a minimum.

Measurement of LNG is a complex activity and dynamic methods are relatively young. Improved devices are needed, but reachable, in order to fulfill the requirements of retail LNG. The characteristics of Retail LNG include a greater number of transfers and operations with decreasing volumes in each step. As such, the Retail LNG market may be well served with measurement processes that are more dynamic and adaptable. Measurement utilizing Coriolis

and ultrasonic meters are joining the well proven means of measurement by weight in many instances. These newer technologies are beginning to play an important role, and at times represent the only feasible alternative for acceptable accuracy in operations. Challenges including a lack of calibration facilities and inadequate means for quantifying installations effects persist. However, with higher investments in these fields it is assumed that these can lead developments suitable for the Retail LNG market.

An excellent reference with regard to best practices of measuring LNG is the GIIGNL Custody Transfer Handbook. This publically available⁵ document should be consulted by participants in the Retail LNG market.

Custody transfer and energy balancing appears to becoming one of the most important commercial considerations that will need to be addressed in the Retail LNG process chain.

8.8 LNG Quality Considerations

As an emerging fuel for transportation and other

⁵ Available at <http://www.giignl.org/publications>

8. Aspects of LNG Supply

markets, LNG poses some significant differences to the liquid petroleum fuels it is intended to replace. Understanding of these differences is important for Retail LNG market participants.

✓ **Pricing** – The method of determining price for a given quantity of fuel, and the resulting energy provided in that quantity, needs to be clear and transparent. LNG historically has been priced on an energy basis while liquid petroleum fuels have been priced on a

volumetric basis. The quality, or composition, and the reconciliation of differences between supply sources and commercial agreements with end users will pose challenges for pricing of the fuel.

✓ **Weathering or Aging** – Throughout the Retail LNG Value Chain the LNG will be continuously warmed by any small heat input entering from the surroundings, vaporizing it and producing vapor (boil off).

As the boiling points of different components within the LNG range widely, from -196 °C to +36 °C those constituents that have the lowest boiling points such as nitrogen and methane boil-off first, changing the initial composition and properties of the LNG. Accounting for these changes along the Retail LNG value change from a commercial standpoint will be challenging.

✓ **Determination of Composition** – In relation

Illustrative Example – Everett Marine Terminal

The Everett Marine Terminal (EMT) outside of Boston Massachusetts, United States, opened in 1971 as a peak shaving facility, predominantly designed to supply LNG to peak shaving facilities via truck. More than 100 trucks can be loaded each day via four LNG loading bays. Over 325,000 trucks have been loaded at the facility since 1971. In recent years, an average of more than 10,000 loadings have taken place at the terminal. Of these there has never been a release of LNG as a result of a vehicle accident.

Supporting the expansion of Retail LNG in the area, the EMT has supplied LNG to such diverse customers as paper mills, greenhouses, laundry facilities, E&P drilling and pressure pumping applications and LNG fueling stations for over the road transportation. Such supply to the transportation market includes the supply to an LNG fueling station which GDF SUEZ Gas NA, the owner and operator of the Terminal, opened in 2012 to seed the nascent LNG truck market in the Northeastern part of the country.



Clockwise from top right; Current EMT Truck loading, LNG Fueling Station, 150,000 loading truck circa 1991, LNG Barge Massachusetts circa 1974

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to the aging issue addressed above, the actual determination of the LNG quality along different points of the Retail LNG value chain will be challenging due to the cost and complexity of the instruments required to accurately determine the composition and physical properties of the LNG. LNG import and export terminal as supply sources are expected to pose few problems since in most cases the equipment and data on fuel composition is in place and available.

- ✓ **Methane Number** – Another aspect of LNG quality, both at delivery to the end user and as the LNG is stored by the end users, is the Methane Number of the LNG. Methane Number is the measure of resistance of fuel gases to engine knock (detonation) and is assigned to a test fuel based upon operation in a knock testing unit at the same standard knock intensity. Pure methane is assigned as the knock resistant reference fuel with a methane number of 100. Pure hydrogen is used as the knock sensitive reference fuel with a methane number of 0 [39]. Market participants should note that several methods exist to calculate methane numbers, and no standard exists today. All depend on different (proprietary) empirical data sets from test engines, and there can

be substantial differences in outcomes for the same composition, so caution is required when using these numbers. While the methane number is of minimal importance for most end users in something like the C&I market, it is very important in applications in which the fuel is being used in internal combustion engines. GIIGNL has recently published a position paper on “Methane Number in Natural Gas Regulation” which can serve as a reference and starting point for market participants [41].

8.9 Regulatory Concerns

Environmental benefits of using LNG as a fuel can be greatly diminished if care is not taken in the reduction or complete elimination of venting of the natural gas to the atmosphere during operations. Commonly termed “methane slip”, the release of unburned natural gas from the operations within the Retail LNG process chain can have negative effects due to the potency of methane in relation to Greenhouse Gas (GHG) effects.

Although efforts are underway in general there are few international, national or local regulations that specifically cover the Retail LNG value chain. The industry can and should draw

upon the large quantity of existing materials that are in place for the traditional LNG process chain and where appropriate adapt such for the regulation of Retail LNG. Please refer to Section 4 of this Handbook.

9. ASPECTS OF LNG USE (END USERS)

Throughout the Retail LNG value chain, it may be end users who represent the most inexperienced LNG participants. As such, great importance will be placed upon the transferring of knowledge from those within the process chain who have experience, to these new participants. Existing codes and standards do not fully cover all relevant issues associated with the Retail LNG value chain, but serve as the best general basis for the design and operation of Retail LNG facilities. As such they should be carefully reviewed by end users and where appropriate applied to the fullest extent possible.

GIIGNL has proposed to extend the scope of this Retail LNG Handbook in the near future, to more fully explore the end user segment of the Retail LNG market. A second phase of GIIGNL's effort will dive deeper into the details associated with end user facilities and provide more color and context to the challenges, issues and opportunities that exist.

The following high level introduction into some of the important aspects of handling LNG in a safe, efficient and responsible manner has been provided as a starting point for market participants.

9.1 End User Safety

The use of LNG at end user facilities will create new hazards compared to the conventional fuels that LNG is usually replacing. Education is critical to the safe handling of LNG. The physical properties of LNG should be clearly understood by market participants and where possible training and introduction to LNG should be made available to personnel involved in the trade.

9.1.1. End User Safety Systems Employed

As with the broader topic of safety, it is education, with regard to the capabilities of available safety systems, that stands paramount. LNG differs from traditional fuels and thus the application of technologies and equipment for Retail LNG must carefully consider these differences to ensure that the intended protection is provided. As mentioned in many of the proceeding sections, the employment of multiple safety layers to manage inherited risk has been a well proven cornerstone to LNG industries approach to safety and similar philosophies should be considered for the Retail LNG market.

9.1.2. End User Procedures

In addition to operational procedures that are developed in conjunction with the facilities designers, vendors and operations personnel, it is important to prepare for emergencies. Utilizing work performed during design on the identification and assessment of risk, emergency procedures should be developed.

As a starting point the discussion on procedures contained in 8.1.2. Procedures of this Handbook should be carefully reviewed by end users. The lessons learned by, and experience of, the incumbent LNG market participants may provide an excellent base from which site specified procedures can be developed.

9.1.3. End User Training

During the design and implementation of end user infrastructure projects, a "training needs analysis" should be completed for personnel that will be engaged in the Retail LNG process chain. This assessment should be comprehensive and address training needs for end user staff, first responders, government officials, inspectors, delivery drivers, etc. who as part of their duties will interact with the Retail

9. ASPECTS OF LNG USE (END USERS)

LNG infrastructure. “Depth of training should correspond to the roles and responsibilities of the personnel; to the complexity of the operations they are involved in and to the type of facilities” [42].

Each of the segments within the Retail LNG market will have unique applications, requiring specific training requirements. Using a training needs analysis and working with industry experts, governmental authorities, first responders and other stakeholders to develop site and application specific training programs is recommended. However, in general, the following themes normally form the basis for Retail LNG training programs:

- ✓ **Basics of LNG Operations** – Training to cover the properties and hazards of LNG. In depth training on the concepts and information addressed in Section 2 of this Handbook. Additional attention to relevant topics such as LNG measurement (flow, density, colorific value, composition, etc.), boil-off, weathering and the cryogenic nature of the fuel.
- ✓ **Emergency Response** – Address the basics of addressing LNG releases and potential LNG fueled fires. The safe handling and use of appropriate PPE and firefighting equipment

and techniques. An understanding of flammability limits, vapor formation and dispersion should be achieved by the trainees Application specific process design issues including the functionality of ESD systems and pressure release devices as well as an examination of potential sources of energy (pumps, vaporizers, etc.) and potential leak points within in the End User system.

- ✓ **Communication** –Training for operators, first responders and other stakeholders likely to be effected during emergency situation on proper communication protocols.

9.2.End User Security Concerns

In many ways, security of facilities may be one of the most site specific issues associated with Retail LNG. As with many of the other aspects of LNG use by end users, much can be gained from reviewing the historical measures taken at LNG facilities within the region of operation. What may be of most benefit however, is the education of local stakeholders on the properties and hazards of LNG. With a sound

understanding of the risk posed by the Retail LNG facilities, collaborative security measures can be identified and implemented.

9.3.End User Staffing Requirements

Staffing requirements should be carefully considered during the design of any end user facilities. Evaluations with regard to the level of automation vs. level (and skill) of staff should be made early and consider normal and emergency conditions.

9.4.End User Equipment Siting

Section 4 of this Handbook presents a summary of international codes, regulations and standards applicable for LNG facilities and operations. Relevant national and local reference documents have also been included. These documents are recommended to be the basis for the siting of LNG infrastructure for End Users. As a matter of best practice, the use of risk assessments, technical feasibility studies, and operational assessments for the siting, design and operation of Retail LNG end user



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facilities is also recommended.

With regard to the siting of End User equipment and infrastructure, an item of particular interest is the consequence of release and the formation and dispersion of vapor from the site. Careful consideration should be given to this issue and appropriate measures taken during the siting of the facilities to mitigate the hazards posed.

End Users should consult section 8.4 Equipment Siting of this Handbook for context and guidance on the siting of End User facilities.

9.5. End User Transfer Operations

Some important differences exist between the transfers of LNG from larger supply facilities and the transfer of LNG into smaller end users. Pressure, is one of the most apparent of these differences. While the majority of large supply facilities will utilize LNG storage which is maintained at essentially atmospheric conditions, many Retail LNG applications will utilize pressurized storage solutions. Issues that are exacerbated at elevated pressures such as reverse flow, pressure relief, de-inventorying, etc. will need careful consideration by the end

users.

In the observed Retail LNG market to date the majority of end use transfers have been directly from a trailer to a stationary tank or vessel. Vessel to vessel, trailer to trailer and other combinations have all also been employed. From the limited experienced gained, and leveraging the history and knowledge base of the larger LNG value chain it appears as if both hoses and fixed loading arms have been demonstrated to be viable for the transfer of LNG at the Retail LNG scale. Each specific application should engage with the local stakeholders, including port authorities, to identify the most suitable transfer operation.

For existing LNG import terminal operators, a careful evaluation should be completed prior to the supply of LNG directly to end user vessels. Impacts to existing operations (i.e. traffic and congestion of jettys) must be carefully weighed against the benefits of expanding services.

The venting of product during transfer, or even normal operations, is an operational issue requiring due consideration by the participants of the Retail LNG market. The venting of product could occur for a variety of reasons with the most common being:

- ✓ Boil-off due to heat leak into storage;
- ✓ Heat gains from LNG pumping operations;
- ✓ Heat leak during bulk transfer from mobile storage (i.e. LNG trailer) to permanent storage;
- ✓ Heat leak during fuelling operations, including the “venting to storage” from mobile (end user) tanks back from the dispensers.

The venting of product has safety, commercial and environmental impacts that could be detrimental to the advancement of the market if not addressed properly. After a review of the heat ingresses into the Retail LNG value chain, the following observations are made with regard to the minimization of heat leak:

- ✓ For LNG transfers utilizing LNG pumps, the proper selection of pump head to properly meet the operating conditions to avoid excess pump power inputs;
- ✓ Good facility designs and optimization minimizing unloading/loading lines and flexible hose lengths (if employed) and diameters. Minimization of fixed process line length and diameter.
- ✓ Good insulation on all fixed piping. The



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insulation of flexible hoses can be challenging and is usually not considered feasible.

- ✓ Good insulation on storage tank insulation.
- ✓ Minimization of pumping activities such as cold recirculation.
- ✓ Minimization of the effects of conditioning systems (need for saturated LNG at the end user) so that the only LNG being dispensed is saturated and the minimum level of heat is returned/added to storage.

accurate flow measurement and other infrastructure such as dedicated weight bridges represent infrastructure that small end users may have a hard time justifying as part of their projects. Lack of such infrastructure, opens the door for conflicts around energy balances.

For End Users the robustness of the Retail LNG process chain may also be an important factor for consideration. Planning for, and having the ability to adapt to unforeseen circumstances along the Retail LNG process chain will mitigate commercial consequences.

9.6. End User Commercial Considerations

As mentioned in 8.7 Measurement of LNG Supply, the custody transfer and energy balancing has been identified as one of the most important commercial considerations that will need to be addressed in the Retail LNG process chain. In particular, transfers of LNG at the end user sites have the potential to become problematic due to lack the appropriate infrastructure. At LNG supply facilities justifications can be made for the types of detailed measurement typically associated with large LNG facilities. Gas chromatographs,



10. Trends and Prospects in Retail LNG

Globally, the prevailing driver for the adoption of LNG as a fuel has been increasingly stringent environmental regulations. Goals to reduce the emissions from marine and on-road vehicles, including CO₂, SO_x, NO_x and particulate matter, have increased the attractiveness of LNG as a transportation fuel. In areas with prolific natural gas resources, there has been an historic divergence in the relative cost of petroleum based fuels and natural gas leading to additional economic advantages for those who can access and utilize natural gas as a fuel.

Two large markets have moved first: over the road transportation and marine. These two markets represent some of the largest users of

petroleum based fuels and even modest conversion rates represent massive potential in terms of volumes of LNG consumed in the Retail LNG market and corresponding environmental benefit. In terms of global CO₂ emissions, the road transportation market is estimated to produce 17%, and the marine market 2%, of emissions to the environment. [43]

A limited number of early adopters in the commercial and industrial market have also been at the forefront of the emergence of the global Retail LNG market. Regionally, as described below, other market participants are actively engaged in Retail LNG.

10.1. Regional Trends and Prospects

One of the common challenges that the Retail LNG marketplace faces throughout the regions, is the problem described by old adage 'chicken or the egg'. Developing a long term viable market requires significant investment in infrastructure such as liquefaction facilities, fuelling and bunkering stations and engines that can burn natural gas. However, the lack of infrastructures creates uncertainty and risk for the end users, subsiding demand. Many

stalemates due to end users desiring security of supply, and Retail LNG suppliers requiring a secure market before committing to infrastructure investments have been observed.

The growth of the market is in question by many participants. According to a recent industry wide survey addressing the challenges, expectations and future for the LNG bunkering industry conducted by Oil & Gas iQ, only 43% of the responding market participants felt that by 2020 LNG would be well-established globally as a marine fuel. Infrastructure, the global conversion, LNG pricing and initial cost were cited as the greatest challenges for the use of LNG as fuel [44].

End use markets (i.e over the road, marine, C&I, etc.) each are challenged with varying market drivers. Within regions some may have success, while others cannot develop. "The use of LNG in Road transportation as a replacement fuel for diesel has proliferated most rapidly in areas with more stringent environmental standards for vehicle emissions, such as the US West Coast, Europe and China" [9].

However, projects are proceeding even in the face of challenges presented by the current low oil price environment. Technological

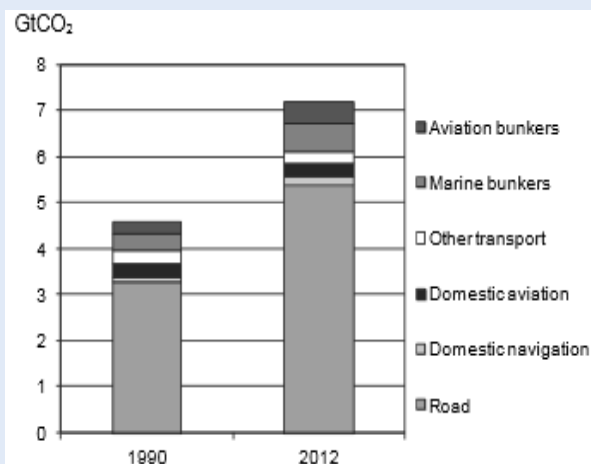


Figure 26 - CO₂ Emissions from transport 1990 and 2012.
Source IEA



10. Trends and Prospects in Retail LNG

advancements, geographical considerations and new uses of LNG have influenced the market for LNG infrastructure at a smaller scale. Some assess that Capex on small scale LNG will reach \$4.59bn in 2015. [20]

The effectiveness and success of early adopters, buoyed in most cases by overwhelming economics, governmental policy or environmental objectives, represent the best chance of moving past these stalemates in the Retail LNG market. LNG Import Terminals can, and are, playing an important role in helping the Retail LNG market break through some of these impasses, by offering services based largely upon a simple expansion of their services.

10.1.1 Trends and Prospects in the Americas

In the United States an increase in gas supply, and the resulting divergence between gas and oil pricing, have played a key role in increasing the market penetration of Retail LNG for end users. For suppliers of Retail LNG looking to invest in new production, the diversification of end users between the different market segments has proven to be a good risk mitigating strategy. Projects that have been

able to identify geographical locations and commercial opportunities in which there is a confluence of demand amongst the market segments have had success. The vast majority of the Retail LNG trade continues to be the well-established over the road fuel for transportation market.

With more than 100 LNG fuelling stations and more than a decade of successful operations the United States have demonstrated the viability of LNG as an important alternative fuel. The rapid increase in production from shale formations and the resulting stabilization of natural gas pricing coupled with more volatile pricing on an energy basis of gasoline and diesel have resulted in the acceleration of adaption of LNG for transportation, especially in several heavy duty segments. Early adopters on the West Coast of the United States have continued to expand their operations and to date essentially half of the LNG stations are located in California [32]. In recent years, an expansion of the LNG fuelling station from the West Coast, moving east, has taken place. And now stations are operating across the country and on both the Pacific and Atlantic seaboard.

In North America, demand for LNG as a fuel substitute for diesel is anticipated to grow.

Driven largely by the substantial price differentials between natural gas and liquid petroleum fuels, environmental emissions and a market supply push, the Retail market is expected to continue to attract the attention of existing LNG operators as well as new market participants.

Due to cost and logistical challenges involved in transporting LNG over large distances the majority of the LNG production for the growing market will be supplied by new, standalone plants. Excess capacity from Import/Export facilities and Peakshaving plants is expected to supplement the supply from the standalone facilities in the regions immediately surrounding those plants. With the large amount of natural gas being processed in North America, additions and modifications to existing gas processing facilities enabling LNG production are also being pursued.

Whereas the majority of the momentum for the adoption of LNG as a transportation fuel has come from private businesses in North America (at times in response to environmental regulations), it is anticipated that governmental initiatives will soon follow. Examples include regions like the Canadian province of British Columbia where a recent released 10 year



10. Trends and Prospects in Retail LNG

transportation plan indicates the strong support of LNG. “The Province will continue to work with First Nations, local and federal governments, ports and industry on land use planning, access and infrastructure needs for proposed LNG facilities throughout the province. The Province will be ready to upgrade provincial infrastructure as needed to support LNG [45].”

In the Caribbean, Central and South America, Retail LNG projects that are addressing stranded demand have gained the most traction. The common term “virtual pipeline” has been used to describe these projects which utilize LNG, supplied by existing LNG Import Terminals or specifically built liquefaction plants, to reach isolated end users. In these areas, where an estimated 75% of the energy is derived from oil based fuels [46], LNG is being considered as organizations are realizing that LNG is less expensive than both low-sulfur and high-sulfur fuel oil. The AES Andres LNG Import Terminal in the Dominican Republic has recently launched trans-shipment and LNG Bunkering services demonstrating the flexibility offered by existing LNG import Terminals. According to AES Corporation the owners of the Terminal, “the combination of AES Dominicana’s ability to procure competitively priced LNG and the

capability to deliver small loads of LNG allow for cost effective conversion solutions for smaller-load fuel consumers in the region” [47].

10.1.2 Trends and Prospects in Europe

In Europe in particular, , government policy has helped to advance the use of LNG as a Fuel. With the support of programs like the European Commission’s LNG Blue Corridor Project, which aims to establish LNG as a viable alternative for medium- and long-distance transport, LNG fuelling stations are expected to continue to be developed across four main transportation corridors. As of 2014 Spain, United Kingdom, Sweden, The Netherlands, Portugal, Belgium, Estonia, Finland and Italy have active LNG fuelling stations [10]. In total there are currently more than 65 LNG or L-CNG stations in Europe [48].

The governmental support, and consequently, the pace at which Retail LNG, and more specifically the infrastructure for Retail LNG has developed over the last years is however different for each European country.

With countries like The Netherlands continuing

to support the development of Retail LNG the growth of the LNG is expected to continue at a modest pace gaining momentum as early adopters build out infrastructure and clarity around the value proposition is gained. In a report assessing the potential of the Retail LNG market prepared for the Dutch Ministry of Economic Affairs, the future prospects for Retail LNG were summarized as follows: “The use of small scale LNG is now in the market development phase, which is characterized by a relatively large amount of uncertainties. We expect that, after gradual growth via early industry adaptors, the market will grow substantially after 2020 [49]. For context supported provided to date has helped the development of infrastructure where over 300 LNG trucks are currently on the road using LNG.

In countries like Belgium, the existing LNG Import Terminal continues to expand the services offered in support of the market development while end users and government backing open up downstream opportunities. Examples would include the Port of Antwerp, where LNG bunkering via truck to vessel has been possible since 2012. After, initial success with the LNG bunkering the port is now looking to establish a shore to vessel solution as early as



10. Trends and Prospects in Retail LNG

2019

At the time of publication of this Handbook, 44 fuelling stations for over the road transportation are now open or in construction in Italy, Portugal, Spain, Sweden, United Kingdom, Netherlands and Belgium [50]. LNG infrastructure for fuelling vessels is at a very early stage, with only Norway and Sweden having developed small-scale LNG terminals for bunkering purposes. The Baltic area seems to have promising development for this infrastructure type as a result of the supply of LNG in this region, regulations in emissions, and also incentives for SOX and NOX emissions reductions in northern Europe.

The first hurdle in the small scale LNG value chain has been to get access to supply close to the main business area location. A regional example would be in the Amsterdam/Rotterdam Area (ARA) where there is available, or under construction, break bulk capacity to serve the Retail LNG market. However, in order to make the LNG available to the shipping segment outside ARA, there is a requirement to transport the LNG to smaller terminals (i.e. 10,000 - 30,000m³) and then further transfer into a bunker vessel or a bunkering barge. Consequently, the transportation and reload

costs have a significant impact on the end price for the end users. In a low oil price market, LNG can be more expensive than heavy fuel oil and at best could be compared to a marine gas oil price.

Adding to the complexity for developing a small scale LNG bunkering value chain is that there is presently hardly any available small scale LNG vessel available in the market, and due to the significant costs (40-50 million EUR for a bunker/feeder vessel 5,000 – 6,000m³) it takes long commitments and a strong financial position to enter into this market. In the ongoing EU funding process (2015) there are several bunkering vessels and related infrastructure projects which have applied for funding, so it is envisaged that this market could expand in the period 2017-2020.

Break Bulk concept in maritime transport of LNG, is also enlarging the logistic chain. Small scale vessels are currently supplying different areas, and even countries, from big scale terminals as it is being done in Nordic Countries. Future developments will be seen in this field, mainly related with the use of LNG as a fuel in maritime transport, but also to supply natural gas to peripheral regions.

Irrespective of the challenges observed to establish a small scale LNG value chain, there is a firm belief that the small scale LNG market will grow in areas like the Baltic. The new LNG terminal capacity in Lithuania and Poland will have the capacity to transfer LNG on rail or truck throughout the entire Baltic region and further east. Companies such as Statoil, Lietuvos are working together to develop small scale LNG operations, joining the likes of Gasum and its subsidiary Skangass AS. Geir Heitmann, Vice President for LNG trading for Statoil has described the Baltic area as follows; “This is a market in its infancy, but is expected to grow quite considerably in years to come.” The LNG arm of Lietuvos, Litgas, has stated that the small scale market in the Baltic Sea is forecasted to reach 0.5 – 1.0 billion m³ by 2020, driven by stricter environmental regulations [51]. There is an underlying incentive to try to reduce the independence from having only one gas supplier in this area, and LNG would be the obvious choice in this respect.

As in North America, where small segmented markets developed independently, the current fueling infrastructure in Europe for both over the road and marine use, is geographically isolated to local routes and ports within



10. Trends and Prospects in Retail LNG

countries. In order to facilitate the development of a single market for alternative fuels for transport in Europe, the European Council has set out a “Clean Power for Transport” package. Namely, Europe wants to break the over-dependence of European transport on oil, which represents a bill up to EUR 1 billion per day, and increasing costs to the environment. The “Clean Power for Transport” package establishes that natural gas (and biomethane) are part of the EU-mix of alternative fuels required to substitute oil as energy supply to transport in the long term.

The “Directive on the deployment of alternative fuels infrastructure” adopted by the European Parliament and the Council on 29 September 2014, sets a regulatory framework for the build-up of natural gas refueling point [52]. Subsequently, by the end of 2016, member states must establish their national policy framework for developing sufficient LNG fuelling infrastructure. The objectives are:

- ✓ by the end of 2025, sufficient LNG refueling stations along the main transport routes to ensure the smooth circulation of LNG-powered vehicles across the European Union, and sufficient LNG refueling infrastructure for ships in seaports;

- ✓ by the end of 2030, sufficient LNG refueling infrastructure for ships in inland ports.

Major multinational initiatives such as the Blue Corridor and the Trans-European Network for transport (TEN-T) programs have been launched to enhance the development of a single market for alternative fuels for transport in Europe and to connect major transportation hubs across the continent. The European union TEN-T program aims to close the gaps between Member States' transport networks, remove bottlenecks that still hamper the smooth functioning of the internal market and overcome technical barriers [53]. TEN-T groups several EU funded projects to kick-start a market uptake of LNG as alternative fuel for shipping and road transport.

The LNG Blue Corridors project is set-up to to demonstrate the use of LNG as a real alternative for medium and long distance transport. The core of the project is the roll out and demonstration of four LNG Blue Corridors (i.e. European main transport routes). This will include building 14 new LNG or L-CNG stations and building up a fleet of about 100 LNG Heavy Duty Vehicles which will operate along the corridors.

In the Mediterranean area, the European

Maritime Safety Agency (EMSA) has recently launched a tender for a study to promote the deployment and development of the alternative fuels infrastructure, and in particular of LNG as fuel for ships. This tender follows EMSA's 2013 “Study on Standards and Rules for bunkering gas-fuelled Ships” demonstrating a continued commitment to advancing LNG as a transportation fuel alternative.

GIIGNL members have entered the market with at least four new projects for their existing LNG import Terminals. These new projects will supplement the Retail LNG activities that the Spanish Terminals have been involved with for years. Here, a robust network of import terminals have supported the distribution of LNG via road trailers for more than 40 years. Work on GIIGNL's Overland Transportation of LNG report indicated that more than 30,000 loadings take place each year in Spain [37].

Finally, the addition of rail to the logistic chain will enhance capillarity to the chain, taking advance of all the advantages of a multimodal solution and being the last piece of the puzzle of the LNG logistic chain.

10.1.3 Trends and Prospects in

10. Trends and Prospects in Retail LNG

the Far East

After the Great East Japan Earthquake occurred in March 2011, the disruption of energy supplies including electricity, oil and gas, revealed the vulnerability of Japan's energy system. Since then, Japan has been paying more attention to energy security and reviewed the Energy Basic Plan principally in April 2014. The new energy plan gives a direction to each energy source, for example, to reduce dependency on nuclear power generation through energy savings and the introduction of renewable energy, as well as to improve the efficiency of thermal power generation. The new energy plan also indicates the importance of reforming the system of both electricity and gas. Currently, each independent city gas company plays a series of roles from LNG receiving and regasification to supplying the city gas to customers in the major consuming regions of metropolitan areas, but after 2022, according to the reform of the gas system, a city gas company will be divided legally into a LNG terminal company and a pipeline company,

Now, in Japan, dependency on natural gas has increased while renewable energy is promoted. This state of the market is expected to continue for the foreseeable future.

The Japanese Government, from the point of view of energy security, environmental loading reduction (CO₂ reduction through fuel conversion of petroleum to natural gas etc.) and the promotion of price competitiveness among city gas companies has started a review of the development of area wide natural gas pipelines which could connect city gas conduit network that are operated independently in each area. However, in order to put this plan into practice a large scale capital investment and a long period of time (Obtaining the permission of Ministry of Land, Infrastructure, Transport and Tourism or of local government and negotiation with the local residents) will be required. So for the time being, according to the area and the scale of demand, the main transportation will be centered on the combination of the pipeline and the LNG trailers. Meanwhile, coastal carriers and freight trains will continue to be utilized primarily in a backup role.

It is currently estimated that there are close to 800 LNG fuelling stations in operation in China and the sale of LNG fuel tractors has increased with individual firms like China LNG Group planning to invest in 100,000-200,000 LNG powered trucks by 2020 [54]. The use of LNG to support the energy needs far outside of the

major cities and pipeline networks of China have led to integrated process chains in which natural gas is liquefied at remote facilities and used locally or trucked thousands of kilometers to end users. Large truck and bus fleets have been converted along with LNG use in power generation and process and industrial facilities. In 2014 alone, 76 new small LNG liquefaction trains were expected to be brought on line which more than doubles China's LNG production capacity [55].

In the short term the growth is expected to continue. However as noted in a recent examination of the history, current status and future prospects of China's Fuel gas sector; "Regulatory reforms will likely be the overarching variable in the future of China's fuel gas sector. The sector remains largely under government control with substantial market distortions from price controls" [56]. Considering such, as more LNG is imported into the country and China's pipeline network is expanded opening up the fuels market to globally index natural gas, the long term prospects for the Retail LNG process chain is uncertain.

Outside of China, economic and environmental drivers may not be sufficient to meaningfully



10. Trends and Prospects in Retail LNG

affect the Retail LNG markets and the proliferation of small Retail LNG value chains may be driven more by the expansion, or opening, of new energy markets within the region.

Japan has had the longest history of operating LNG process chains that closely resemble the Retail LNG process chain described herein. Distribution of LNG via small costal tankers and ISO containers has been well proven as the Japanese Import terminal operators serve isolated load centers throughout the country. As population centers grow and expand and as new LNG import terminals are brought online, it is expected that additional small LNG value chain will be created.

In addition to the major LNG export projects, Australia also has been using small LNG process chains, which utilize supply from small



Figure 27 - LNG Road Train (Source CEM International)

liquefaction facilities to serve industrial and residential needs, for many years. Recently, the mining and power generation sectors have started to participate in these process chains. The unique transportation method of LNG via “road trains” is commonly used in the country.

In 2012, DNV managed a comprehensive Joint Industry Project (JIP) in Australia that closely examined the industry and regulatory requirements concerning the marine bunkering of LNG. The findings of this study were similar in nature to many of the observed trends in the other regions. “One of the most common key barriers to a more widespread adoption of LNG as a fuel for vessels seems to be insufficient local LNG supply and immature bunkering infrastructure coupled with a lack of regulatory schemes for both shore-based and ship-to ship bunkering. The feasibility of LNG fuelled shipping depends on the simultaneous development of the entire value chain; the lack of such concurrent evolution is a major challenge and means increased investment risk for each stakeholder [42].

The construction of new large scale LNG Terminals and the expansion of services from existing Terminal in countries such as Korea, Thailand, India and Indonesia represent a

potential “hub” for the wider distribution of LNG within region. Retail LNG appears to be a suitable solution to the challenges imposed by the countries dispersed landmass and segmented areas of demand.

10.2. Technology Trends and Prospects

“On the back of innovations in small-scale liquefaction and engine technology, the spread of gas to transport may yet have the potential to become a second wave of the LNG business” [57]. Smaller LNG infrastructure projects associated with the Retail LNG market are challenged to deliver cost effective solutions to customers within reasonable timeframes. One of the most prevalent observed trends with regard to the technology within the Retail LNG space is vendor solutions which offer standardization while still allowing a fair amount of flexibility needed to meet project specific requirements. An example of a Retail LNG component that has seen such “standardization” while still providing a great deal of “flexibility” would be over the road trailers. In recent years as the demand for over the road trailers has increased, design and manufacturing

10. Trends and Prospects in Retail LNG

improvements have led to offerings with increased capabilities while reducing the end cost to the customers. Enhancements have included more storage capabilities, lighter weights, better handling, additions and/or provisions for onboard vaporization, etc. providing the end users with flexible transportation storage platforms to build out logistical value chains.

In a similar vein, cost reduction derived from optimizing and standardizing existing LNG technologies and then combining many discrete “packages” into systems that meet project requirements, or are well suited to particular markets, has been observed.

Vendors and technology suppliers across the full range of technologies are making incremental improvements to their offerings. Considering the overall cost to Retail LNG projects, it's the advancements of the “major components” that warrant the most attention. For example, LNG storage represents one of the largest investments in a Retail LNG project. While shop fabricated storage tanks have a long and solid history for small LNG facilities advancements in prefabrication and modularization for field erected tanks are being made. The double wall vacuum insulated vessels relies the use of

expensive stainless steel suitable for cryogenic services. A current research activity has seen initiatives in developing alternative materials and construction methods that offer a cheaper solution. This includes the transfer of technologies such as membrane tankage normally associated with LNG carriers to the Retail LNG space.

Another technological driver in development of retail LNG is miniaturization. In case of low demand, smaller and smaller tanks are available in the market at decent prices opening the possible to supply small industries and population centers.

10.3. Operational, Safety and Security Trends and



Figure 28 - LNG Truck loading (Source: ENGIE)

Prospects

Firstly, the gradually adoption of established standard and laws such as the ADR by many countries will help sets similar rules, and help form the main pillar of safety. These rules define procedures, documents and traceability of the LNG transported, from origin to destination. As has long been the tradition for LNG industry, safety should remain first: In the vast majority of applications standards and laws like ADR are setting the minimum requirements and industry is adding additional measures on top of those requirements to help ensure the long and successful safety record of the LNG industry is maintained. Regional harmonization of safety measures would also be an important contribution to improving safety throughout the

10. Trends and Prospects in Retail LNG

Retail LNG value chain.

Key components of the Retail LNG value chain are the overland and marine transportation marine of LNG. These methods have had a long history of success and are poised to become a real alternative to supply natural gas to potential customers. Fortunately, with an experience of more than 45 years LNG transportation with high levels of development, LNG participants are positioned to being capable to offer products and services that can compete with traditional energies. These products and services are being offered with safety and a security of supply due in large part to a good mixture of regulation, know-how and good practices. Customers are benefiting from a robust logistic chain that delivers fuel without any appreciated difference from that of pipelines.

The development of commercial and operational solutions that allow for a transparent product while maintaining operational and logistical flexibility will be a challenge for LNG suppliers such as LNG import terminals. Minimizing losses and uses within the terminals when processing and handling volumes that are many time less than what the facilities were designed for will also require innovation and proper application of available technologies.



11. Conclusion and Recommendations

As surmised by the GIIGNL's TSG at the outset of their endeavor, virtually every member company had historical experience with, was in the midst of expanding its services to include, or was actively engaged in the study of, Retail LNG.

As a representative body of experienced, long term LNG Import Terminal operators, GIIGNL stresses the importance of managing the inherent risks associated with LNG, the application of suitable codes and standards and the use of proper equipment. This Handbook and the study of the aspects of LNG supply and use including safety, security, staffing, equipment siting, and operations provides is intended to provide an illustrative framework from which the industry can jointly move towards best practices.

While Retail LNG is considered by many to be "new" there is substantial historical experience with all aspects of the market. LNG Import Terminals, including the experience and competence of their staffing, can play a key role not only in the incubation and growth of the Retail market, but also in the molding and shaping of an adequate regulatory framework, of applicable codes and standards and operational best practices. This Handbook has been produced to serve as a starting point, guide

and reference for the participants of this emerging market.

11.1.1 Conclusion and Summary of Observed Trends

There is a global imperative to transition to LNG as a fuel for many markets. Driven largely by environmental regulations and fuel supply economics this transition is in its infancy. While promising, the advantages of LNG observed in today's market (i.e. cost and environmental benefit) may dissipate in the future as new technologies or natural gas pricing fundamentals change.

Retail LNG liquefaction facilities and end user infrastructure have different project economics than those of the traditional LNG industry. It is expected that uncertainties with regard to the regulatory factors and value proposition currently driving the market will continue to foster significant hesitancy for market participants in the Retail LNG market. The different nature of Retail LNG process chain as compared to the traditional LNG process chain suggests that market participants will have to find creative solutions and offer innovative products to the Retail market. The natural gas,

and more specially the LNG market, will continue to be dynamic, posing significant challenges for market participants looking to invest in the space. Significant Retail LNG developments will probably only occur if driven by government policy or if private businesses, acting as early adopters, take on the risk of these challenges.

With regard to the Retail LNG market, the following representative examples of themes observed by GIIGNL's TSG are provided:

- ✓ Properties and Hazards of LNG – The inherent risks associated with LNG that have been observed and carefully mitigated for close to five decades exist in the Retail LNG market. Although there are differences in scale and scope between the markets, the lessons learned and practices employed by LNG Import Terminal operators provide the Retail LNG market with demonstrative guidance on what prudent operations can look like. Understanding the hazards of LNG, managing the associated risks and maintaining operational protocols and operator knowledge are imperative for all participants of the Retail LNG market.
- ✓ Codes and Standards – Industries involved in LNG trade, governments, class societies and

11. Conclusion and Recommendations

other interested parties have worked together for many years to create codes, standards, rules and regulations that represent the collective knowledge of the participants and the current best practices within the industry. These documents can reflect the “state-of-the-art” in terms of technologies and capture the operational best practices that have been gained through actual technical design processes, operational experience, research and development and testing. However, regional differences in the application of particular codes and standards still exist. While the current operation of LNG Import Terminals is viewed as having a robust and well proven set of codes and standards, it has been recognized that the scale and scope differences that exist with Retail LNG have produced “gaps” in coverage that should be addressed with the drafting of focused codes and standards.

- ✓ Current Market – Retail LNG market drivers were identified and illustrative value propositions detailed. Although it was confirmed that significant opportunity exist for participants in the LNG value chain, GIIGNL’s TSG has found that many proposed Retail LNG developments appear to have overstated the economic benefits that can

be derived. The market drivers for the adoption of LNG as a fuel vary from region to region. Additionally, the drivers for adoption will vary within the different end user markets. However, it can be stated that the main drivers will be environmental benefits (e.g. compliance with regulations) and lower cost.

- ✓ Equipment – As with other “emerging” markets, there can exist a corresponding emergence of new technologies and improvement in existing technologies. While some advancement with regard to the equipment utilized in the Retail LNG value change is being observed, much of the improvement has been found to be in the “economies of scale” that have arisen due to increased utilization of proven equipment and technologies.
- ✓ Availability of LNG Supply – Challenges exist in balancing the level of LNG demand and availability of LNG supply. Despite these challenges, LNG Import Terminals have been confirmed as ideal “hubs” in a distributive model of LNG supply to the retail markets. They provide the basic infrastructure required to supply these markets and can be modified or expanded to perform new services and add new distribution

capabilities.

- ✓ Aspects of LNG Supply – With regard to safety, security, staffing, equipment siting, and transfer operations LNG import terminals provide excellent references for developing Retail LNG facilities and for conducting safe and efficient Retail operations.
- ✓ Trends and Prospects – The general level of interest in Retail LNG that can be observed in the press and trade publications has been observed by GIIGNL’s member companies. Although the industry “buzz” is substantial, volumes of LNG traded in the Retail Market currently and for the foreseeable future will only represent a small percentage of the global LNG trade. However, even these modest volumes will offer many opportunities for current and new LNG market participants to develop new business, expand their services, and increase utilization of existing infrastructure. The environmental benefits are significant, the technology employed is well developed, and the economics workable in many cases.

11.1.2 Recommendations for Moving Toward Transportation



11. Conclusion and Recommendations

Best Practice throughout the Retail LNG Value Chain

As the supply of LNG to Retail market grows, it will be imperative that the level of care and custody that the historical LNG industry has provided be maintained by all Retail LNG market participants. Industry knowledge, and the collective lessons learned of the broader LNG industry, need to be shared with new entries.

- ✓ Procedures – Support the development of focused, targeted and standardized procedures for operational activities like bunkering in the marine space, or tank filling in the C&I/transportation space.
- ✓ Boil-off management – Development of commercially feasible and operationally effective measures to manage the boil-off within the LNG process chain.
- ✓ Standard connections - Standardization of Retail LNG equipment and transfer interfaces to minimize the chance of releases along the Retail LNG process chain. Ensuring compatibility between suppliers, transporters and end users will be significant for the effective and safe growth of the Retail LNG market.

- ✓ Industry Outreach – Support the dissemination of LNG knowledge and experience throughout the LNG value chain. Key focused on operational safety and the maintaining of the high safety standard of the LNG Industry. Support to standardization authorities and governments in the development of technical standards necessary for the Retail LNG market.

commercially focused aspects of the Retail LNG value chain.

11.1.3 Recommendations for Continuance and Expansion of Study

As originally planned by the TSG, an expansion of the study to look more closely at end users is recommended. Effort in determining if knowledge and experience from the traditional process chain is successfully being transferred throughout the Retail LNG process chain is suggested. Particular focus should be paid to the commercial considerations as well as end user installations and operations.

It is recommended that GIIGNL's Commercial Study Group play a pivotal role in the expansion of the Handbook and supplement the technical and operational information contained with



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Appendix 1: List of LNG Import Terminals

Country	Site	Storage	Total Capacity in liq m ³	Send-out		Owner	Operator	Start-up date of the terminal
		Number of tanks		Number of vaporizers	Nominal capacity in NG Bcm/y			
AMERICAS								
Argentina	Bahia Blanca <i>*(F)</i>		151 000	6	5.1	YPF	YPF	2008
	Escobar <i>*(F)</i>		151 000	6	5.1	UTE Escobar (50% Enarsa, 50% YPF)	YPF	2011
Brazil	Bahia <i>*(F)</i> - Golar Winter		137 000		8.3	Owner: Golar / Charterer: Petrobras Owner: Excelerate Energy / Charterer: Petrobras Owner: Golar / Charterer: Petrobras	Petrobras	2013
	Guanabara Bay <i>*(F)</i> - Excelerate Experience		173 400		5.0		Excelerate Energy	2009
	Pecem <i>*(F)</i> - Golar Spirit		129 000	2	2.5		Petrobras	2009
Canada	Canaport LNG	3	160 000	8	10.0	Repsol (75%), Irving Oil (25%)	Repsol Canada Ltd	2009
Chile	Mejillones	1	175 000	3	2.0	Codelco (37%), GDF SUEZ (63%)	GNLM	2010
	Quintero	3	334 000	3	3.7	Terminal de Valparaiso S.A (40%), ENAP (20%), Endesa (20%), Metrogas (20%)	GNL Quintero S.A.	2009
Dominican Rep.	Punta Caucedo	1	160 000	2	2.3	AES	AES	2003
Mexico	Altamira	2	300 000	5	7.8	Terminal de LNG de Altamira (Vopak 60%, Enagas 40%)	Terminal de LNG de Altamira (Vopak 60%, Enagas 40%)	2006



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	Energia Costa Azul	2	320 000	6	10.3	Sempra	Sempra	2008
	Manzanillo	2	300 000		5.2	Samsung (37.5%), Kogas (25%), Mitsui (37.5%)	Kogas	2012
Puerto Rico	Penuelas	1	160 000	2	3.8	Gas Natural Fenosa (47.5%), GDF SUEZ (35%), Mitsui (15%), GE (2.5%)	Eco Electrica	2000
U.S.A.	Cameron LNG	3	480 000	10	15.5	Sempra	Sempra	2009
	Cove Point	5	380 000	10	10.7	Dominion Cove Point LNG	Dominion Cove Point LNG	1978, restarted 2003
	Cove Point Expansion	2	320 000	15	8.0	Dominion Cove Point LNG	Dominion Cove Point LNG	2008
	Elba Island	5	535 000	11	16.3	Southern LNG (Kinder Morgan)	Southern LNG	1978, restarted 2001, expanded 2006, expanded 2010
	Everett	2	155 000	4	6.9	GDF SUEZ	GDF SUEZ	1971
	Freeport LNG	2	320 000	7	18.0	Freeport LNG Development, L.P.	Freeport LNG Development, L.P.	2008
	Golden Pass	5	775 000	8	21.4	QP (70%) Exxon (17.6%), Conoco Philips (12.4%)	Golden Pass LNG	2010
	Gulf LNG Energy	2	320 000		12.0	Kinder Morgan (50%), GE (40%), AES (10%)	Gulf LNG Energy	2011
	Lake Charles	4	425 000	14	24.3	Trunkline LNG	Trunkline LNG	1982, Infrastructure enhancement project completed March 2010
	Northeast Gateway *(F)		151 000	6	4.1	Excelerate Energy	Excelerate Energy	2008



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	Sabine Pass	5	800 000	16	41.4	Cheniere Energy	Cheniere Energy	2008
America Total7 311 400249.6								
ASIA								
China	Dalian	3	480 000	3	4.1	Petrochina (75%), other companies	Petrochina	2011
	Guangdong Dapeng, Shenzhen	3	480 000	7	9.2	CNOOC (33%), BP (30%), other companies	GDLNG	2006
	Dongguan, Guangdong province	2	160 000		1.4	Jovo Group		2013
	Fujian	2	320 000		3.6	Fujian LNG (CNOOC 60%, Fujian Inv. & Dev.Co. 40%)	CNOOC	2008
	Hainan	3	480 000		3.0	CNOOC	CNOOC	2014
	Qingdao	3	480 000		4.2	Sinopec	Sinopec	2014
	Rudong, Jiangsu	2	320 000	3	4.8	Petrochina (55%), other companies	Petrochina	2011
	Shanghai, Mengtougou	3	120 000		0.2	Shanghai Gas Group	Shanghai Gas Group	2008
	Shanghai LNG	3	495 000		4.1	Shanghai LNG (CNOOC 45%, Shenergy Group Ltd 55%)	CNOOC	2009
	Tangshan (Caofeidian)	3	480 000		4.8	Petrochina	Petrochina, Beijng Enterprises	2013



Appendix 1: List of LNG Import Terminals

	Tianjin <i>*(F) - GDF SUEZ Cape Ann</i>	2	60 000		3.0	Owner: Höegh LNG (50%), MOL (48.5%), Tokyo LNG Tanker Co. (1.5%) / Charterer: GDF SUEZ - relet to CNOOC for 5 years	Höegh LNG	2013
	Zhejiang, Ningbo	3	480 000		4.1	CNOOC (51%), other companies	CNOOC	2012
	Zhuhai (Gaolan)	3	480 000		4.8	CNOOC	CNOOC	2013
India	Dabhol	2	320 000	6	2.4	Ratnagiri Gas & Power Ltd (GAIL, NTPC)	Gail	2013
	Dahej	4	592 000	19	12.5	Petronet LNG	Petronet LNG	2004, expansion in July 2009
	Hazira	2	320 000	5	6.9	Hazira LNG Private Ltd (Shell 74%, Total 26%)	Hazira LNG Private Ltd	2005
	Kochi	2	368 000	6	6.3	Petronet LNG	Petronet LNG	2013
Indonesia	Lampung LNG <i>*(F) - PGN FSRU Lampung</i>		173 000	3	2.4	Owner: Höegh LNG / Charterer: PGN LNG	Höegh LNG	2014
	Nusantara Regas Satu <i>*(F)</i>	6	125 016	6	4.1	Owner: Golar LNG Charterer: Nusantara Regas	PT Nusantara Regas (JV Pertamina & PGN)	2012
Japan	Chita	7	640 000	11	14.8	Chita LNG	Chita LNG	1983
	Chita Kyodo	4	300 000	14	9.9	Toho Gas / Chubu Elec	Toho Gas	1978
	Chita-Midorihamma Works	2	400 000	8	10.5	Toho Gas	Toho Gas	2001
	Fukuoka	2	70 000	7	1.1	Saibu Gas	Saibu Gas	1993
	Futtsu	10	1 110 000	13	26.0	Tokyo Electric	Tokyo Electric	1985
	Hatsukaichi	2	170 000	4	1.2	Hiroshima Gas	Hiroshima Gas	1996
	Hibiki	2	360 000	5	2.9	Hibiki LNG (Saibu Gas 90%, Kyushu Electric 10%)	Hibiki LNG	2014
	Higashi-Ohgishima	9	540 000	9	18.0	Tokyo Electric	Tokyo Electric	1984



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Himeji	8	740 000	6	6.4	Osaka Gas	Osaka Gas	1984
Himeji LNG	7	520 000	8	11.0	Kansai Electric	Kansai Electric	1979
Ishikari LNG	1	180 000	3	2.3	Hokkaido Gas	Hokkaido Gas	2012
Joetsu	3	540 000	8	3.2	Chubu Electric	Chubu Electric	2011
Kagoshima	2	86 000	3	0.3	Nippon Gas	Nippon Gas	1996
Kawagoe	6	840 000	7	6.7	Chubu Electric	Chubu Electric	1997
Mizushima	2	320 000	6	5.8	Mizushima LNG	Mizushima LNG	2006
Nagasaki	1	35 000	3	0.2	Saibu Gas	Saibu Gas	2003
Naoetsu	2	360 000	4	2.0	INPEX Corporation	INPEX Corporation	2013
Negishi	14	1 180 000	13	13.8	Tokyo Gas /Tokyo Electric	Tokyo Gas /Tokyo Electric	1969
Niigata	8	720 000	14	11.6	Nihonkai LNG	Nihonkai LNG	1984
Ohgishima	4	850 000	11	12.8	Tokyo Gas	Tokyo Gas	1998
Oita	5	460 000	6	6.3	Oita LNG	Oita LNG	1990
Sakai	3	420 000	6	8.7	Kansai Electric	Kansai Electric	2006
Sakaide	1	180 000	3	1.6	Sakaide LNG	Sakaide LNG	2010
Senboku I	2	90 000	5	2.9	Osaka Gas	Osaka Gas	1972
Senboku II	18	1 585 000	15	15.7	Osaka Gas	Osaka Gas	1977
Shin-Minato	1	80 000	3	0.4	Gas Bureau, City of Sendai	Gas Bureau, City of Sendai	1997
Sodegaura	35	2 660 000	37	41.5	Tokyo Gas / Tokyo Electric	Tokyo Gas / Tokyo Electric	1973
Sodeshi	3	337 200	8	3.9	Shimizu LNG (Shizuoka Gas 65%, TonenGeneral 35%)	Shimizu LNG	1996
Tobata	8	480 000	9	10.3	Kita Kyushu LNG	Kita Kyushu LNG	1977
Yanai	6	480 000	5	3.1	The Chugoku Electric	The Chugoku Electric	1990
Yokkaichi LNG Centre	4	320 000	8	8.7	Chubu Electric	Chubu Electric	1987
Yokkaichi Works	2	160 000	6	2.9	Toho Gas	Toho Gas	1991



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Korea	Gwangyang	4	530 000	2	2.3	Posco	Posco	2005
	Incheon	20	2 880 000	43	56.4	Kogas	Kogas	1996
	Pyeong-Taek	23	3 360 000	39	51.5	Kogas	Kogas	1986
	Samcheok	3	600 000	8	14.7	Kogas	Kogas	2014
	Tong-Yeong	17	2 620 000	20	33.7	Kogas	Kogas	2002
Malaysia	Melaka * (F)		260 000	3	5.2	Petronas	Petronas Gas	2013
Singapore	Jurong	3	540 000	5	7.8	SLNG	SLNG	2013
Taiwan	Taichung	3	480 000	8	6.0	CPC	CPC	2009
	Yung-An	6	690 000	18	12.8	CPC	CPC	1990
Thailand	Map Ta Phut	2	320 000	4	7.3	PTT	PTT LNG	2011
Asia Total			36 226 216		549.9			
MIDDLE EAST								
Dubai	Jebel Ali *(F) - Golar Freeze		125 850		4.9	Owner: Golar / Charterer: Dubai Supply Authority	Golar	2010
Israel	Hadera * (F)		138 000	6	4.8	INGL	Excelerate Energy	2013
Kuwait	Mina Al Ahmadi *(F) - Golar Igloo		170 000		7.9	Owner: Golar / Charterer: KPC	Golar	2014
Middle East Total			433 850		17.6			



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EUROPE								
Belgium	Zeebrugge	4	380 000	12	9.0	Fluxys LNG	Fluxys LNG	1987
France	Fos-Cavaou	3	330 000	4	8.3	Fosmax LNG (Elengy 72.5%, Total 27.5%)	Elengy	2009 (commercial operation from April 2010)
	Fos-sur-Mer	3	150 000	12	5.5	Elengy	Elengy	1972
	Montoir-de-Bretagne	3	360 000	11	10.0	Elengy	Elengy	1980
Greece	Revithoussa	2	130 000	6	5.0	DESFA S.A.	DESFA S.A.	2000
Italy	Offshore Livorno * (F)	4	135 000	3	4.1	OLT (E.ON 48.2%, IREN Group 49.1%, other 2.7%)	ECOS (Exmar, Fratelli Cosulich)	2013
	Panigaglia	2	100 000	4	3.3	GNL Italia S.p.A.	GNL Italia S.p.A.	1971
	Rovigo (Gravity Based Structure)	2	250 000	5	8.0	Qatar Petroleum (22%), Edison (7,3%), ExxonMobil (70,7%)	Adriatic LNG (Qatar Petroleum, Edison, Exxon)	2009
Lithuania	Klaipeda * (F) - FSRU Independence		173 000	4	4.0	Owner: Höegh LNG / Charterer: Klaipedos Nafta	Höegh LNG	2014
Netherlands	Rotterdam	3	540 000	8	12.0	Gasunie (47,5%), Vopak (47,5%), OMV (5%)	Gate Terminal	2011
Portugal	Sines	3	390 000	7	7.6	Ren Atlântico	Ren Atlântico	2004
Spain	Barcelona	6	760 000	13	17.1	Enagas	Enagas	1969
	Bilbao	3	450 000	4	7.0	Enagas, Infrastructure Arzak 2, BV, EVE	Bahia de Bizkaia Gas, SL (BBG)	2003
	Cartagena	5	587 000	9	11.8	Enagas	Enagas	1989
	Huelva	5	619 500	9	11.8	Enagas	Enagas	1988

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	Mugardos	2	300 000	3	3.6	Gas Natural Fenosa, Endesa, Xunta Galicia, Sonatrach, Tojeiro Group, Galicia Government, Caixa Galicia, Pastor, Caixanova	Reganosa	2007
	Sagunto	4	600 000	5	8.8	Union Fenosa Gas(42.5%), Oman Oil(7.5%), Osaka Gas (20%), Deutsche Asset & Wealth Management(30%)	Saggas	2006
Turkey	Aliaga/Izmir	2	280 000	5	6.0	Egegaz	Egegaz	2006
	Marmara Ereglisi	3	255 000	7	6.2	Botas	Botas	1994
United-Kingdom	Dragon	2	320 000	6	7.6	BG Group (50%), Petronas (50%)	Dragon LNG	2009
	Isle of Grain	8	1 000 000	14	20.5	National Grid	Grain LNG	2005
	South Hook LNG	5	775 000	15	21.3	Qatar Petroleum International (67.5%), Exxon Mobil (24.15%), Total (8.35%)	South Hook LNG Terminal Company Ltd	2009
	Teesside ^{*(F)}		138 000		4.2	Excelerate Energy	Excelerate Energy	2007
	Europe Total	74	9 022 500		202.7			
	GLOBAL TOTAL		52 993 966		1 019.8			

**(F) Floating technology*





International Group of Liquefied Natural Gas Importers

Media/Industry Inquiries:

Vincent Demoury

+33 1 56 65 51 56

vincent.demoury@giignl.org

Groupe International des Importateurs de Gaz naturel Liquéfié

8 rue de l'Hôtel de Ville - 92200 Neuilly-sur-Seine - France

Phone: + 33 1 56 65 51 60

E-mail: central-office@giignl.org – web site: www.giignl.org