Common Guidelines for LNG Bunkering Operations at Spanish Ports

BOOK I - TECHNICAL GUIDE

EU Core LNGas hive Project (ET1)

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Book I: Technical Guide

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Core LNGas hive:

CLEAN POWER FOR TRANSPORT

The project is developing a safe and efficient, integrated logistics and supply chain for LNG in the transport industry (small scale and bunkering), particularly for maritime transport of the Iberian Peninsula.

ET 1 Study:

Technical, Safety & Environmental Specifications on LNG

Analyse operational procedures for LNG supply in different technologies, both in maritime and port services in order to reach a set of tested specifications.

Lead by:

Organismo Público Puertos del Estado (OPPE)
Dirección General de la Marina Mercante (DGMM)

Aim of the Common Guidelines:

This guidance document aims to assist the Spanish Port Authorities (PA) in the process of facilitating the safe and environmentally responsible supply of LNG as a marine fuel in their area of responsibility. The document aims to equip PAs with relevant information that delivers knowledge about the characteristics of LNG as a marine fuel product, equipment and supply methods, as well as potential risks, authorized areas and mitigation measures, the role and responsibilities of the stakeholders involved, and the training of the personnel involved in supply operations.

Use of Book I:

This book is intended to provide knowledge and recommendations on all aspects of the LNG bunkering activity. After a general introduction to LNG as bunkering fuel, if follows with eight thematic chapters covering subjects such as: regulation, equipment, procedures, personnel, roles and responsibilities, risks assessment, etc. Each topic is presented as a unit of knowledge and is broken down into the most relevant aspects that the PA should know about, including recommendations when there are alternatives. References to other sources of regulations, standards, or industry recommendations are also provided for the consideration of the PA.

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Common Guidelines for LNG Bunkering Operations at Spanish Ports

This Guide has been prepared within the framework of the CORE LNGas hive project with the aim of assisting the Spanish Port Authorities (PA) in the process of facilitating the safe and environmentally responsible supply of LNG as a marine fuel in their area of responsibility. The Guide aims to equip PAs with the relevant information that delivers knowledge about the characteristics of LNG as a marine fuel product, equipment and supply methods, as well as potential risks, authorized areas and mitigation measures, the role and responsibilities of the stakeholders involved, and the training of the personnel involved in supply operations.

This Guide does not intend to substitute nor override existing regulations, nor standards or industry guidelines and recommendations; instead, it aims to assist PAs on adopting the right references to establish the safety operational framework that best suits the port requirements while ensuring regulatory compliance.

Background

Maritime transport, like other sectors of the economy, must address the challenge of decarbonization and reduction of polluting gases. LNG provides a significant reduction in emissions when considered as an alternative marine fuel to oil derivatives. LNG will also allow for the partial or total incorporation of renewable gases: biogas or hydrogen derivatives. In this context, LNG is expected to gain share as a marine fuel in the coming years while new carbon-neutral fuel technologies are developed and matured. This guide will remain valid as long as the non-fossil LNG properties consumed onboard are comparable with conventional natural gas. In order to promote LNG as a marine fuel, Directive 2014/94/EU established objectives for member countries to facilitate the supply of LNG in ports of the European core transport network (TEN-T) by 2025.

Ports have facilitated the safe bunkering of conventional marine fuels for many years by developing world-class safety procedures and standards. Due to the low ignition point and cryogenic characteristics of LNG as a fuel product, LNG bunkering in a port requires planning, risk analysis and implementation of specific safety procedures.

While this guide is solely focused on LNG bunkering, the methodologies developed by this guide would be a valid blueprint for use when planning for the implementation and provision of other alternative future marine fuels.

The role of the port

Efficient bunkering services, offering a wide range of energy products, improve the competitiveness of the port attracting traffic and increasing port services activity. Therefore, it is in the interests of the port to develop its bunkering service offering and infrastructure to support this activity. This guide will not address the commercial development of the bunker activity but rather focus on the safety and environmental technical aspects that relate to the landlord and regulator role of the port.

As port space landlords, PAs should determine the locations where bunkering operations can be performed and plan for future needs in bunkering services development. As regulators of the port activity, PAs should ensure that minimum safety and environmental procedures are defined and implemented by the corresponding stakeholders. Through the licensing and authorization process the port will ensure operators can apply all the necessary means and procedures required. It is the role of the port to monitor compliance with procedures and agreed regulations during regular port operations by all the stakeholders involved and to adapt its requirements to the potential impact of changes affecting them. Safe and environmentally friendly LNG bunkering operations at port require the coordination of the two main players in operations, those being the receiving vessel and the bunkering supplier, as well as other players, namely the terminal where the operation takes place, and the PA shore and marine traffic control and emergency response personnel who participate in the operation. It is the role of port to establish the framework to facilitate an efficient and safe coordination among all these stakeholders.

With the support of this Guide, PAs will be able to address the planning stage prior to the development of LNG bunkering activities in their ports, establishing the framework of minimum-safe conditions in the LNG supply later in the authorization phases. PAs will be evaluating how operators comply with technical safety considerations to access the operation license and obtain supply authorization. Finally, during the management phase, PAs need to supervise the correct provision of the day-to-day services, and the incorporation of new operations in compliance with the established security and safety procedures.

It is the objective of this Guide to equip ports with the necessary knowledge to allow them to undertake the necessary actions and properly address all their competencies when it comes to facilitate the safe provision of LNG bunkering at their premises in compliance with their binding regulation.

Using the guide

This guide is structured in two separate and closely intertwined books:

- **BOOK. I TECHNICAL GUIDELINES to safe and environmentally friendly LNG bunkering**

  This book is intended to provide knowledge and recommendations on all different aspects of the LNG bunkering activity. After a general introduction to LNG as bunkering fuel, if follows with seven thematic chapters covering subjects such as: regulation, equipment, procedures, personnel, roles and responsibilities, risks assessment, etc. Each topic is presented as a unit of knowledge and is broken down into the most relevant aspects that the PA should know about, including recommendations when there are alternatives. References to other sources of regulations, standards, or industry recommendations are also provided for the consideration of the PA.

- BOOK. II PROCEDURE GUIDE for LNG bunkering operations at Spanish Ports

  This book is oriented to call PA to action and assists PA in the implementation of the Common Guidelines in its port. It provides clear procedures that PAs should follow when planning LNG bunkering operations to take place within the port, when establishing the technical requirements to grant licenses and when managing the day-to-day supervision of the LNG bunkering at the port. This book content is also intended to align with the Spanish Port System governance and regulation.

To facilitate its usage, both books contain direct link references to chapters, sections or tables contained in the same book, the other book and in other external references. These references will be identified by the following [actions links] . Additionally, the following text color code is used throughout BOOK II: **Text in red, represents a call for attention to important information that needs to be addressed by the PA. Text in blue is used to indicate recommendations based on best practices on specific subjects.**

Ports Authorities already familiar with the LNG bunkering activity could use BOOK II as a reference to assure compliance with all port's obligations by comparing their current regulatory framework with the Guide. Those ports approaching LNG bunkering for the first time are encouraged to read BOOK I first, at least those sections related to the expected service mode: truck to ship, ship to ship or pipe to ship.

Although the Guide deals mainly with guidance for PA to comply with their competences, it is also considered a valuable source for future operators planning to offer LNG bunkering services in Spanish ports, ship owners or agents planning to use these services, terminal operators that will host such operations and regional/municipal safety agencies hosting the ports.

General adoption of the framework of this guide by the Spanish Port System will ease the complexity to both operator offering services in more than one port and vessels calling at Spanish ports. As the guide is based on EMSA, ISO and other widely adopted industry guidelines and standards, the Spanish ports would become aligned with the core of the European framework and requirements related to procedures for LNG bunkering.

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Glossary of Terms and Definitions

All ISO 20519 definitions apply.

Accredited Body – in the context of LNG bunkering, an accredited body is recognized as having the competence and experience in carrying out the certification work against international standards of components, equipment, software and systems forming part of the LNG bunkering system.

Boiling-Liquid-Expanding-Vapor Explosion (BLEVE) – a phenomenon resulting from LNG tank rupture, where LNG contained under pressure is rapidly depressurized, causing a nearly instantaneous transition from liquid to vapour. A BLEVE results in the release of a large aerosol followed by a fireball.

Boil-Off Gas (BOG) – Boil-Off Gas (BOG) is the continuously evaporated or boiled LNG vapor that causes the pressure inside the tank to rise due to heat entering the cryogenic tank during storage and transportation, which changes the quality of LNG over time. This BOG is generated primarily due to heat leakage from the atmosphere through tank insulation, loading, unloading and recirculation in pipeline systems. It can be reliquefied through a boil off gas liquefaction plant and sent to tank storage facility or pressurized and heated for designated service in fuel gas consumers.

(LNG) Bunker Asset – describes the truck, ship (or barge) or fixed storage tank arrangement containing the LNG, including appropriate LNG transfer system able to undertake bunkering operations to the receiving ship.

Bunkering – operation of transferring LNG fuel to a vessel. (ISO 20519 definition)

Bunkering Facility Operator (BFO) – the company responsible for the operation of the bunkering facility.

Bunkering System – is the interconnected system comprising of LNG bunkering equipment, components, piping, transfer hose and control software in the LNG bunkering asset and receiving vessel forming an integrated system for the purpose of safely transferring LNG.

Bunkering Station – fuel receiving stations, usually at an upper deck level, port and starboard, furnished with safety systems, valves, elbows, pressure gauges, filters and relief valves required to manage the transfer of the product.

Bunkering Terminal – fixed operation on or near shore that is not regulated as a vessel that can be used to provide LNG bunkers to a receiving vessel. (ISO 20519 definition)

Certification – refers to the evaluation and confirmation of the LNG bunkering system and operations against recognised standards, mandatory rules and regulations. The evaluation will include the form factor, functionality and characteristics of an LNG component, equipment, software, system but also operational practices such as bunkering procedures, emergency response and the qualification of personnel.

Classification – describes the verification and validation activities relevant to the structural strength and integrity of the ship's hull and its appendages, and the reliability and function of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship in order to maintain essential services on board. Classification Societies achieve this objective through the development and application of their own Rules and by verifying compliance with international and/or national statutory regulations on behalf of Maritime Flag Administrations.

Classification Society – non-governmental organization that establishes and maintains technical standards for the construction and operation of vessels and offshore structures. (ISO 20519 definition)

Controlled Zones – areas extending from the bunkering manifolds on the LNG receiving vessel and the LNG supply source during LNG bunkering operations that have restrictions in place. These restrictions include limitation on personnel access, sources of ignition and unauthorized activities. The controlled zones are subdivided into hazardous zones, safety zones and the monitoring and security areas. (ISO 20519 definition)

Dangerous Goods – dangerous goods or hazardous goods are solids, liquids, or gases that can harm people, other living organisms, property, or the environment.

Dry-Disconnect/Connect Couplings – are specialised couplings, with self-sealing capability that allows for the quick and spill free, connection and disconnection of LNG transfer hoses and piping between the LNG bunkering asset and the receiving vessel.

Emergency-Release Coupling (i.e. dry break-away couplings) – is a specially designed coupling that links the LNG bunkering asset and the receiving vessel's LNG transfer hose. It can disconnect automatically with minimal LNG release upon exceeding a pre-defined separation force. There are two valves at either end that close immediately upon separation, preventing LNG from leaking out of the separated transfer pipe/hose segments.

Emergency Release System (ERS) – an integrated system designed to protect the LNG transfer system (e.g. piping attached to mechanical arms, hose supported by intermediate structure) in case of excessive movement, beyond its defined working envelope. The emergency release system works by automatically isolating and disconnecting either end of the LNG transfer system, allowing a receiving ship to safely separate from the bunkering asset. Also see ESD II emergency release functionality.

Emergency Shutdown System (ESD) – is an integrated system designed to minimize the consequences of different LNG emergency scenarios. This includes hazards emerging from upsets, failures of the LNG bunkering operation but also external hazards such as collisions, adjacent fire that pose safety consequences to the LNG bunkering. There are two types of ESD activation, ESD I results in the controlled stoppage and isolation of the LNG bunkering system. ESD II initiates the abrupt stoppage, isolation and separation of the LNG bunkering system.

Flash Point – is the lowest temperature at which a liquid can generate vapour that in turn can form an ignitable mixture in air near the surface of the liquid. In general, the lower the flash point, the easier it will be to ignite the fluid. HFO has a minimum flash point of 60 ºC while LNG has a flash point of up to -188 ºC.

Failure Modes and Effects Analysis (FMEA) - is the process of breaking down and reviewing elementary (replaceable) parts forming a component or equipment to identify their potential failure modes including their root causes and consequent effects.

Gas – a fluid having a vapor pressure greater than 0.28 MPa at 37.8 ° C.

Harbour Master: Official who is in charge of marine port traffic according to article 266 of Consolidated Legislation of Ports and Merchant Navy – RDL 2/2011

Hazard - is something that has the potential to cause harm to people, assets and the environment. LNG bunkering hazards come from a variety of sources such as equipment failure, human error, etc.

Hazard Identification (HAZID) study - is a method for identifying relevant LNG hazards in order to prevent and reduce any adverse impact that could cause harm to personnel, including the damage or loss of asset and environment.

Hazard and Operability (HAZOP) study - is a systematic process of understanding the hazards in the LNG bunkering equipment, control software and systems to define and understand different vulnerability during operations.

Hazardous (Area) Zone - an area in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of personnel and asset. These special precautions refer to the requirements for the construction, installation and use of components and equipment described in BS EN 60079 -10-1.

Higher Flammable Limit (HFL) – defines the concentration of flammable gas/vapour in air above which there is excessive amount of the combined vapour/gas with air to sustain the combustion. In case of methane the HFL is about 15% volume in air.

Holding time: Time of the pressure increase in the inner tank measured from a starting pressure of 0 bar at the corresponding boiling point of liquefied natural gas (LNG) (−164° C) up to the maximum allowable working pressure (MAWP) of the inner tank.

Inerting – is the systematic process of replacing LNG gas vapours, but also displacing oxygen (air) during empty condition of LNG tanks, piping and equipment, using an inert fluid such as nitrogen (N2).

International Safety Management Code - An IMO code standard for the safe management and operation of ships, and for pollution prevention. Operators of ship's subject to the International Safety Management Code are required to effect a management system (ISM) that meets the code and have their compliance with the ISM audited, first by the Company (internal audit) and then each 2.5 to 3 years by the Flag State Maritime Administration to verify the fulfilment and effectiveness of their Safety Management System.

LNG (Liquefied Natural Gas) – methane gas stored in liquefied form at approximately -163 ºC and atmospheric pressure conditions.

LNG Bunker Management Plan (LNGBMP) – IACS defines an LNG bunker management plan as an integrated document used by the bunker provider and receiving vessel to agree technically and commercially on methodology, flow rate, temperature, pressure of the delivery of LNG and receiving tank. This plan gathers all the information, certificates, procedures, and checklist(s) necessary for an effective and safe LNG bunkering operation.

LNG Transfer System - as defined in ISO 20519 consists of all components and equipment between the bunkering manifold flange on the bunkering asset providing LNG fuel and the bunkering manifold flange on the receiving LNG fuelled vessel. This will include but is not limited to; Ship to ship transfer arms, LNG articulated rigid piping and hoses, Emergency Release Coupling (ERC), insulating flanges and quick connect/disconnect couplings (QC/DC), bunkering control software, ESD Ship/Shore Link or Ship/Ship link used to connect the supplying and receiving ESD systems.

Lower Flammable Limit (LFL) – defines the concentration of flammable gas or vapour in air below which there is insufficient amount of the combined vapour and air to support and sustain combustion. In case of methane the LFL is about 4.5% volume in air.

Management System – set of procedures an organization needs to follow in order to meet its objectives. (ISO 20519 definition)

Manoeuvring – for the purpose of this guideline, a ship is said to be manoeuvring when it is either:

-Making its final approach to another ship for the purpose of mooring alongside the other to perform a ship to ship bunkering operation; or

-Separating from another ship following an unmooring operation until both ships are safely clear of each other.

Member State Authority – legal authority within a member state that has jurisdiction over maritime or port activities within that state. (ISO 20519 definition)

Mobile Facility – mobile facilities are trucks, rail car or other mobile device (including portable tanks) used to transfer LNG to a vessel. (ISO 20519 definition)

Monitoring and Security Area – area around the bunkering facility and vessel where vessel traffic and other activities are monitored to mitigate harmful effects. (ISO 20519 definition)

Permitting - is an official and documented process of formally providing consent to LNG bunker providers granting them the authorization to build, implement and operate the LNG bunkering within the port. This is achieved via the analysis and demonstration of compliance with regulations and standards relevant to the LNG permitting process.

Person In Charge (PIC) – for each bunkering operation, a qualified person in charge (PIC) for the receiving vessel and a person in charge for the LNG provider shall be assigned. These people shall have no other duties during the bunkering operations that can interfere with them performing their duties as a person in charge including being able to activate the ESD immediately if an unsafe condition occurs. (ISO 20519 – 6.5.2.1.)

Port Authority (PA) – is the public body responsible for running and managing the state-owned ports under its operation. The PA reports to the Ministry of Development and is governed by Spanish Legislative Royal Decree 2/2011 of 5 September under which the recast text of the Spanish Law on State-Owned Ports and the Merchant Navy was passed.

Port Service Provider (PSP) – port service providers are operators of tugs, lighters, barges, line handling boats, pilotage services, as well as any other contractors/providers that use the port facilities, being previously licensed by the Port Authority.

Qualification – describes the attainment of an individual, in demonstrating their knowledge and experience in the correct and safe operation of LNG bunkering operations. Qualifications are achieved via the successful completion of educational and training programs relevant to LNG bunkering.

Receiving Ship Operator (RSO) – the company responsible for the operation of the receiving ship, particularly during the bunkering operations.

Receiving Vessel (RV) – ship to be bunkered.

Recognized Organization (RO) – competent organization with delegated authority on behalf of an Administration to assist in the uniform and effective implementation of IMO Codes and Conventions. (ISO 20519 definition)

Restrictions – describes the limitations in terms of the function, usability and capability of components, equipment, and systems relevant to LNG bunkering operations.

Risk – is the combination of the severity/consequence of a given hazard including its probability of occurrence given its historical statistics.

Risk Matrix (level of risk) - is a matrix that is used during LNG bunkering risk assessment to define the level of risk by considering the category of probability or likelihood against the category of consequence severity. This is a mechanism to increase visibility of risks in LNG bunkering and assist decision making in terms of changes and/or operational mitigations.

Safety Zone – area that is defined and enforced during LNG bunkering operations within which only essential personnel are allowed and potential ignition sources are controlled. The extent of the safety zone can be defined by the worst credible leakage analysis or alternatively via quantitative risk assessment.

Security Zone – closely follows the safety zone required during LNG Bunkering, for the purpose of establishing a wider perimeter in order to control access, road traffic and other port activities in the vicinity of the LNG bunkering operation.

Shipowner – a shipowner is the owner of a merchant vessel (commercial ship) and is involved in the shipping industry. In the commercial sense of the term, a shipowner is someone who equips and exploits a ship, usually for delivering cargo at a certain freight rate, either as a per freight rate (given price for the transport of a certain cargo between two given ports) or based on hire (a rate per day). Shipowners typically hire a licensed crew and captain rather than take charge of the vessel in person. Usually, the shipowner is organized through a company, but also people and investment funds can be shipowners. If owned by a ship company, the shipowner usually performs technical management of the vessel through the company, though this can also be outsourced or relayed onto the shipper through bareboat charter.

SIMOPS = Simultaneous Operations – defined as two or more activities that occur at the same time, one of which involves a LNG Bunkering process, and the combination of which may lead to an increased safety risk. Parallel activities include, but are not limited to, disembarkation / boarding of passengers and / or crew, picking up passengers, vehicle loading / unloading, cargo handling, refuelling or lubrication, cleaning / repair work etc. (ISO 20519 definition)

Technical Specification - refers to a set of documented requirements to be satisfied by the LNG bunkering system including its components, equipment, software, and safety provisions. ISO and API are technical standards that normally form the basis of technical specifications.

Technical Standards – standards that prescribe requirements for one or more of the following: operations, equipment design/fabrications or testing methodology. Auditors cannot issue a certification or approval to a company that claims compliance with a Technical Standard unless that standard is incorporated into a recognized management system as a management objective. (ISO 20519 definition)

Terminal Operator (TO) – the entity responsible for a physical part of the Port and for the conduct of an operation or range of operations that take place within it.

Transfer Arm – articulated metal transfer system used for transferring LNG to the vessel being bunkered. It can be referred to as a “loading arm” or “unloading arm”. (ISO 20519 definition)

Vapour Management System (VMS) – is the system via which the PSP and the RSO during bunkering operations should ensure that no LNG vapours (methane) will emit to the environment as a result of normal bunker transfer. A vapour management system should be fully integrated with the bunkering Operating Procedures to ensure that no vapour pressure throughout the LNG bunkering operation will exceed the relief valves maximum operating pressures resulting in over pressurization and relief. BOG generation is the most important aspect to be managed within a VMS.

Vessel – includes ships, barges (self-propelled or no propulsion) or boats of any size in domestic or international service. A bunkering vessel (BV) is a vessel used to transport LNG to a vessel using LNG as a fuel. A receiving vessel (RSO) is a vessel that uses LNG as a fuel and does not transport LNG as a cargo. (ISO 20519 definition)

Zoning – in the context of LNG bunkering operations, zoning is essential to establishing areas of safe refuge from accidental LNG release and its further consequences.

Acronyms

Abbreviation	Description
ADR	European Agreement Concerning the Transport of Dangerous Goods by Road
ALARP	As Low As Reasonably Practicable
BLEVE	BLEVE - Boiling liquid expanding vapour explosion
BFO	Bunkering Facility Organisation
BOG	Boil-Off Gas
EMSA	European Maritime Safety Agency
ERS	Emergency Release System
ERC	Emergency Release Coupling
ESD	Emergency Shut Down
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode and Effects Consequence Analysis
FSRU	Floating Storage and Regasification Unit
HAZID	Hazard Identification Study
HAZOP	Hazard Operability Study
IACS	International Association of Classification Societies
IAPH	International Association of Harbors and Ports
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (Gas Carrier Code)
IGF	International Code of Safety for ships using Gas or other low-flashpoint fuels
IR	Individual Risk
ISM	International Safety Management Code
ISO	International Organisation for Standardisation
LBB	LNG Bunkering Barge
LBT	LNG Bunkering Truck
LBV	LNG Bunkering Vessel
LFL	Low Flammability Limit
LNG	Liquefied Natural Gas
LNG BSS	LNG Bunkering Specification Sheet
LOC	Loss of Containment (of LNG)
LR	Lloyd’s Register
LRV	LNG Receiving Vessel
LSIR	Location Specific Individual Risk

Abbreviation	Description
MTTS	Multi truck to ship
NECAs	Nitrogen Emission Control Areas
PA	Port Authority
PERC	Powered Emergency Release Coupling
PIC	Person In Charge
PPE	Personal Protective Equipment
PSP	Port Service Provider
PTS	Pipeline to Ship (i.e. Fixed storage tank piping)
QCDC	Quick Connect-Disconnect Coupling
QRA	Quantitative Risk Assessment
RA	Risk Analysis
RAM	Risk Assessment Matrix
RO	Recognised Organisation
RPT	Rapid Phase Transition
RSO	Receiving Ship Operator
RV	Receiving Vessel
SECAs	Sulphur Emission Control Areas
SGMF	Society of Gas as Marine Fuel
SIGGTO	International Gas Tanker and Terminal Operators
SIMOPs	Simultaneous Operations
SMS	Safety Management System
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
STS	Ship to Ship
TO	Terminal Operator
TTS	Truck to Ship
UFL	Upper Flammability Limit
WPCI	World Ports Climate Initiative

1. General knowledge of LNG bunkering

1.1. LNG as a bunkering fuel

The adoption of LNG as a bunkering fuel is expanding across the globe, with new bunkering infrastructure being built in Europe, Asia and North America.

The graphs below shows a projected progression of ships in service that would be capable of using LNG as main fuel; while there were about 200 LNG fuelled-capable ships globally at the beginning of 2021, available market data and research indicates a surge in LNG fuelled ships, especially large tonnage vessels, accounting for more than 15% (excl. LNG carriers) of the tonnage under construction at the time of writing[1].

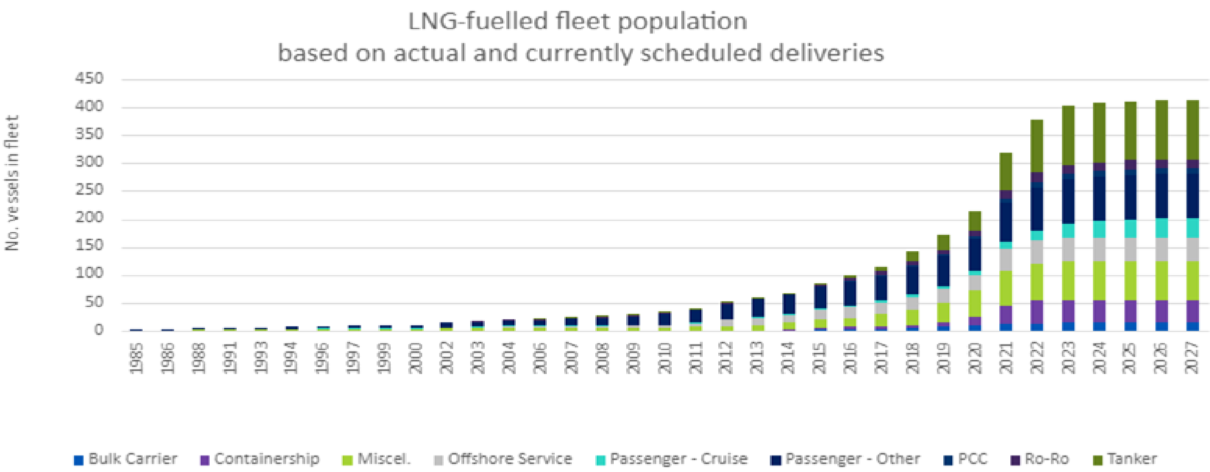


Figure 1.1 LNG fuelled fleet on operation and orderbook. Source: Clarkson, November 2020

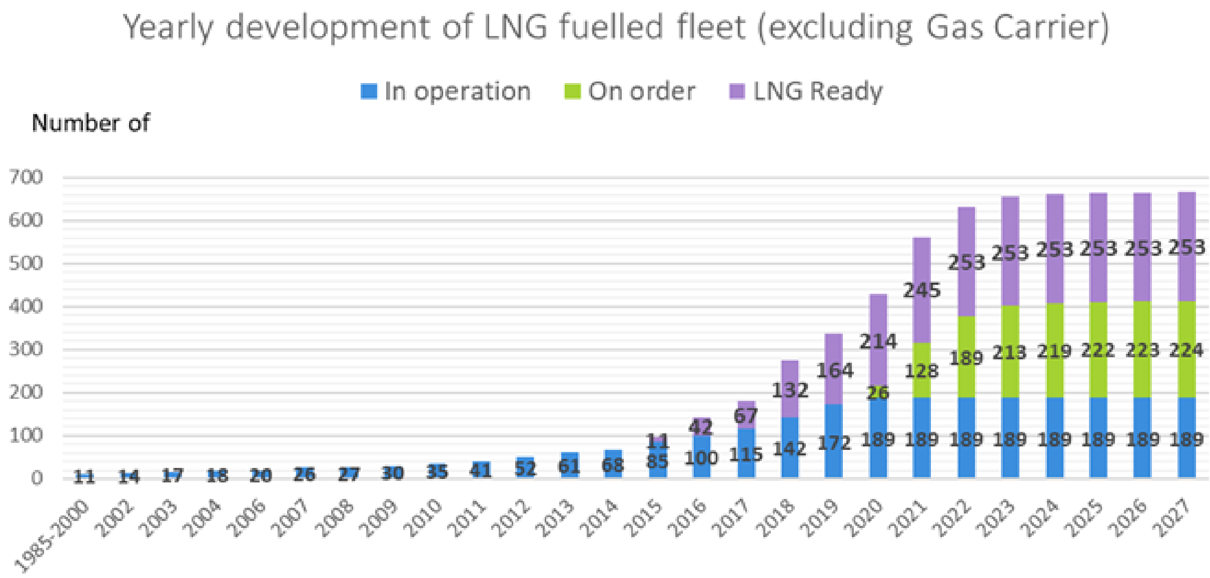


Figure 1.2. LNG fuelled ships and LNG Ready ships. Source: Clarkson, November 2020

[1] https://splash247.com/more-than-a-quarter-of-all-tonnage-under-construction-will-use-alternative-fuels/

The following table show a list of most of the currently operating LBV / LBB and their main characteristics:

Ship Name	Owner	Type	Year	Capacity (m³)	Conversion	Port of bunkering operations	1st LNG bunkering operation	
							Date	Ship Name
Seagas	Sirius Shipping	LBV	2013	180	✓	Stockholm	03-2013	Viking Grace
Green Zeebrugge	NYK Line	LBV	2017	5000		Zeebrugge	14-06-17	Auto Eco
Coralius	Sirius Veder Gas	LBV		5800		-	19-09-17	Fure West
Cardissa	Shell	LBV		6500		Rotterdam	04-10-18	Gargarin Prospect
Oizmendi	Naviera Urbasa, Ibaizabal Group	LBV	2018	600	✓	Bilbao and Cantabrian Coast	03-01-18	Ireland
Coral Methane	Anthony Veder	LBV		7500	✓	Santa Cruz de Tenerife	16-01-19	AIDAnova
Clean Jacksonville	TOTE Maritime	LBB		2200		Jacksonville	Not published	Isla Bella Perla Del Caribe
Kairos	Babcock Schulte Energy	LBV		7500		Klaipeda	15-04-19	Fure Valö
LNG London	LNG Shipping	IWW LBV	2019	3000		Rotterdam	06-19	Containerships Polar Containerships Nord
Flexfueler001	Titan LNG	LBB		1480		Amsterdam	14-06-19	Kvitnos
Kaguya	Central LNG Marine Fuel Corp.	LBV	2020	3500		Chubu region	20-10-20	Sakura Leader
Gas Agility	MOL	LBV		18600		Rotterdam	08-11-20	CMA-CGM Tenere
Avenir Advantage	Avenir	LBV		7500		Pasir Gudang	09-11-20	Siem Aristotle
Flexfueler002	Titan LNG	LBB		1480		Antwerp	-	Not known
Q-LNG 400	Q-LNG	ATB	2021	3996		Jackonsville	27-01-21	Siem Aristotle
FueLNG Bellina	FueLNG	LBV		7500		Singapore	24-03-21	CMA-CGM Scandola
Avenir Accolade	Avenir	LBV	2021	7500		Pasir Gudang	26-04-21	Avenir Advantage

Figure 1.3. LNG Bunkering Vessels and Barges. Source: Clarkson, October 2021

LNG as a bunkering fuel is forecast to be much in demand at all major Ports, both for domestic / coastal trades as well as for ships trading internationally with expected demand surging more than twenty-fold in the next ten years[2].

Many Ports have become or are becoming ready to supply LNG as bunkering fuel for ships as part of their own bunkering infrastructure, or through bunkering services, depending on the method chosen to perform the transfer of the fuel to the LNG fuelled ship.

While the LNG fuelled ship fleet grows, the growth of a small fleet of LNG Bunkering Vessels (LBV) and of LNG Bunkering Barges (LBB) is also proliferating globally, enabling the early adoption of LNG as a bunkering fuel, capable of supplying large volumes of LNG to deep sea ships; 15 such ships are already expected to be in operation globally by 2021. A summary of main locations with LNG bunkering available is showed in Figure 1.4.

[2] https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/091120-lng-bunkering-forecast-to-grow-thirtyfold-to-30-mil-mt-by-2030-pavilion-energy

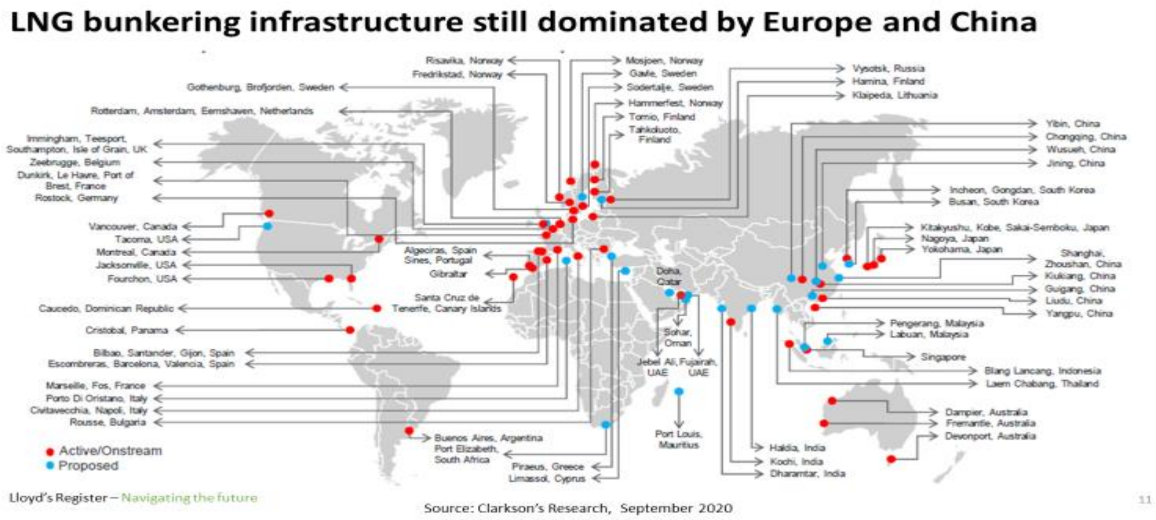


Figure 1.4 LNG bunkering supply infrastructure (09-2020). Source: Clarksons

1.2. LNG Characteristics

Natural gas (NG) is a mixture of methane (the main constituent) and other low molecular weight hydrocarbons (such as ethane and propane). LNG is natural gas that is kept in liquid form at low temperatures (-163 ºC) close to atmospheric pressure. The liquefaction process requires that contaminants such as water and carbon dioxide are removed, so that the concentration of such contaminants in LNG, and natural gas produced by vaporizing LNG, is considered low.

The characteristics of LNG are shown on the table below:

Table 1.1 Marine fuels technical characteristics

Selected Properties	LNG	MGO	HFO
Flash Point (°C)	-188	>60	>60
Auto ignition temp (°C)	595	250	750
Density (kg/m^3)	450	857	983.5
Calorific value (MJ/kg)	55 (Average)	43	40.5
Energy density (MJ/m^3)	24,750 (Average)	36,850	39,830
Flammable range	5 - 15%	0.6 - 7.5%	0.5 - 5%

1.2.1. Hazards Unique to LNG Bunkering

Natural gas, when released from containment as a gas, or when generated by vaporization of a release of LNG, forms flammable mixtures in air between concentrations of 5 and 15 % vol/vol. Although natural gas at ambient temperature is less dense than air, the natural gas vapour generated by LNG at -163°C is approximately 1.5 times denser than air at 25°C. Hence the cold vapour generated by vaporization of LNG behaves as a dense cloud.

Different types of fire hazards may arise, depending on whether it is gaseous natural gas or LNG that is released. These fire hazards include jet fires, flash fires and pool fires. In certain circumstances, vapour cloud explosions (VCEs) may also occur.

1.2.2. Jet Fires

A jet fire is a strongly directional flame caused by burning of a continuous release of pressurized flammable gas (in this case natural gas) close to the point of release. Ignition may occur soon after the release begins; or may be delayed, with the flame burning back through the cloud (i.e. as a flash fire) to the source. Jet fires may result from ignited leaks from process equipment (vessels, pipes, gaskets etc.) and pipelines. A jet fire may impinge on structures or other process equipment, giving a potential for escalation of the incident. The intensity of thermal radiation emitted by jet fires can be sufficient to cause harm to exposed persons.

1.2.3. Flash Fire

Flash fires result from ignition of a cloud of flammable gas or vapour, when the concentration of gas within the cloud is within the flammable limits. In this case, the flammable cloud may be generated by:

A release of pressurized flammable gas (i.e. natural gas).
Vaporization of a pool of volatile flammable liquid (i.e. LNG).

Typically, a flash fire occurs as a result of delayed ignition, once the flammable cloud has had time to grow and reach an ignition source. In the absence of confinement or congestion, burning within the cloud takes place relatively slowly, without significant over-pressure. It is assumed that thermal effects are generally limited to within the flame envelope where there is a high probability of casualties.

1.2.4. Pool Fires

Ignited releases of flammable liquids (including LNG) tend to give rise to pool fires. As with jet fires, ignition of the liquid pool may occur soon after the release begins or may occur as a result of flashback from a remote ignition source if the liquid is sufficiently volatile to generate a cloud of flammable vapour.

1.2.5. Vapour Cloud Explosion

When a cloud of flammable gas occupies a region, which is confined or congested, and is ignited, a vapour cloud explosion result. The presence of confinement (in the form of walls, floors and / or a roof) or congestion (such as the pipes, vessels and other items associated with process plant) in and around the flammable cloud results in acceleration of the flame upon ignition. This flame acceleration generates blast overpressure. The strength of the blast depends on several factors, including:

- The reactivity of the fuel
- The degree of confinement or congestion
- The size of the congested / confined region occupied by the flammable cloud
- The strength of the ignition source

It should be noted that a variety of objects may act as confinement / congestion, in addition to those normally encountered on process plant.

1.2.6. Rapid Phase Transition

If LNG is spilt on to water, it usually forms a boiling pool on the water surface. However, under certain circumstances, LNG released on to water can change from liquid to vapour virtually instantaneously. The effect has been observed in some experiments involving LNG but is not well understood. A Rapid Phase Transition (RPT) can generate overpressure and dispersion of vapour. Any damage from the overpressure generated tends to be quite localized. Rapid phase changes have not resulted in any known major incidents involving LNG.

1.2.7. Cryogenic Burns and Inhalation

The extremely low (cryogenic) temperature of LNG means that it can cause burns if it comes into contact with exposed skin. Furthermore, inhalation of the cold vapours generated by LNG can cause damage to the lungs.

1.3. LNG Value Chain

The LNG value chain includes gas extraction and production, its subsequent liquefaction, then its multi-modal transport to different end-users. Considering an LNG fuelled vessel, there are at least three delivery modes such as LNG bunker trucks, LNG bunker barges and ships and finally a local LNG storage tank with fixed LNG piping.

EMSA Guidance on LNG Bunkering describes the LNG Value Chain in its section 2.3:

From Natural Gas source to final consumers the LNG value chain can assume different shapes and be designed in different ways, depending on the needs for a variety of end-users. Figure 1.5 below shows a very simplified representation of a generic value chain, distinguishing between two different types of consumers: 1) LNG and 2) NG consumers.

These typically represent the transport and domestic/industrial users, respectively. The chain is characterized by the liquefaction and re-gasification points where NG transforms into LNG and vice-versa. The need for LNG is associated with 2 (two) essential needs: a) the need to transport NG through long distances or b) the need to provide NG for mobile users.

Since LNG occupies 600 times less volume than NG it is also convenient for storage wherever limited space is available. This is obviously the case for ships, and other mobile units, but can also be the case for land-side developments, off-grid, potentially close to shore where LNG use may be convenient.

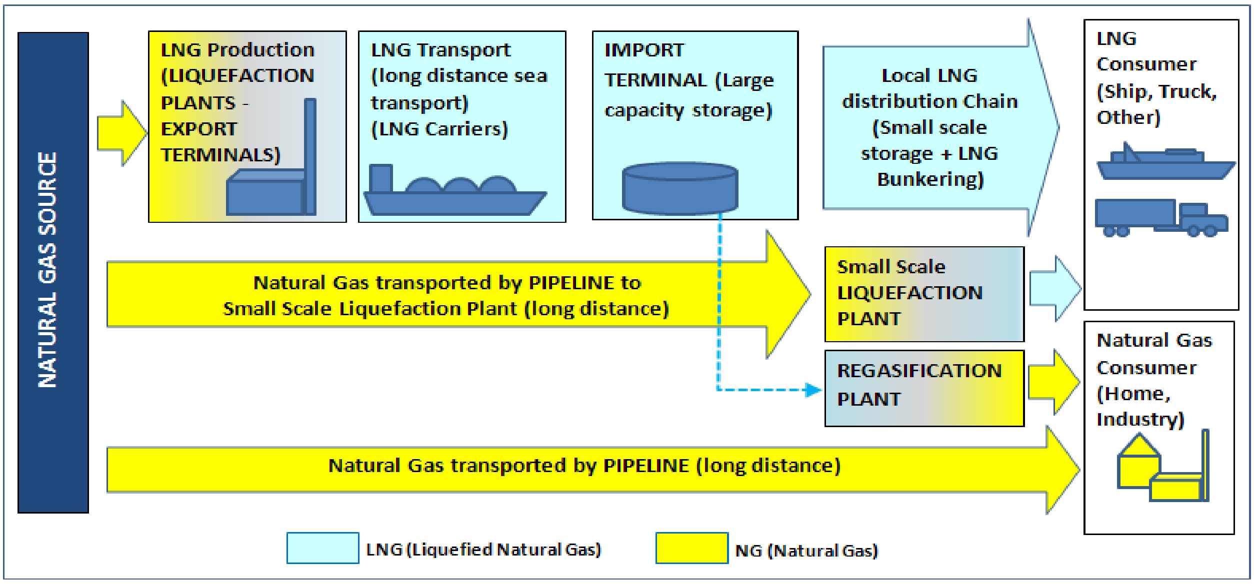


Figure 1.5 LNG global market value chain. Fuente: EMSA Guidelines

Finally, it is important to note that a significant part of the LNG value chain can be contained within the boundaries of a Port, especially if a multi-modal hub is also included, it will very likely be seen the co-existence of different stakeholders in the port area. Port rules and local regulations should not only have taken this notion into account but also realize the different regulatory frameworks that may be relevant for different parts of the LNG chain. Fixed LNG bunkering facilities and mobile units may coexist, demonstrating the versatility of LNG as a fuel.

The LNG value chain from an import grid or natural gas network distribution can be further decomposed into different supply routes. Figure 1.6 shows a possible representation of different supply routes. Different stages are considered from the figure: 1) Supply; 2) Transport; 3) Local storage or production and 4) Bunkering. Only LNG fuelled vessels as the consumers are represented in the figure. However, this would be a multi-consumer environment that would be able to access LNG/NG from any point in the LNG chain.

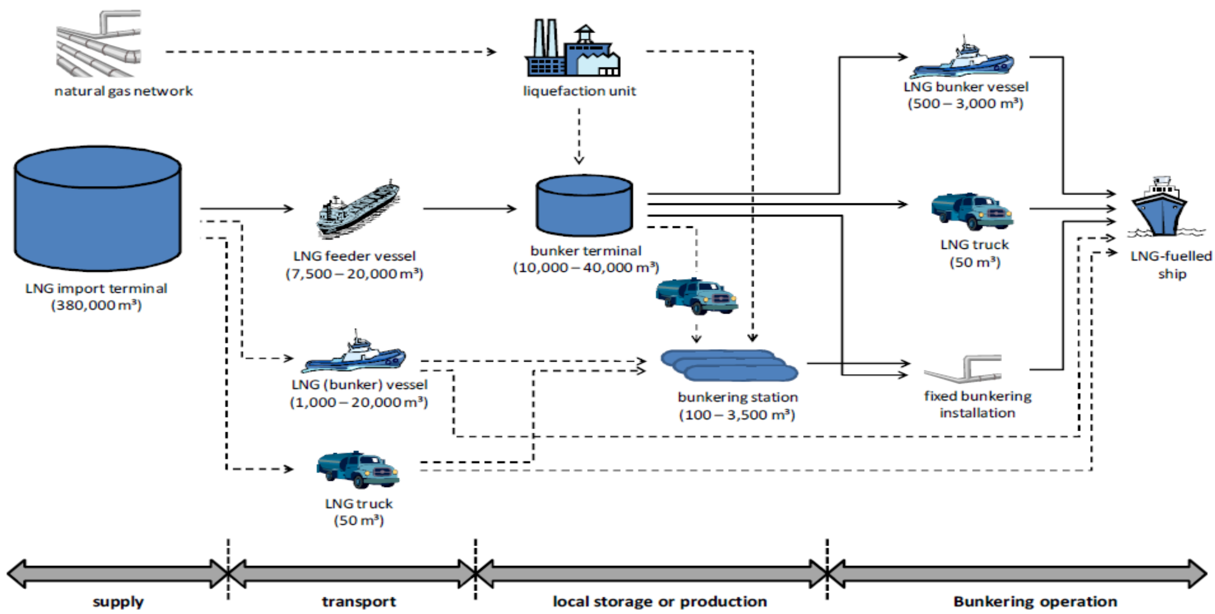


Figure 1.6 LNG as fuel supply chain. Fuente: EMSA guidelines

2. LNG Bunkering Technology

LNG bunkering technology has already been developed to undertake bunkering operations at Ports for a range of transfer methods including LNG bunkering vessels, LNG bunkering barges and LNG fuelled (receiving) ships.

From the storage facility or terminal there are three methods to deliver the LNG to the end user:

1. Truck to Ship, with a single Truck, TTS, or several Trucks, MTTS.
2. Ship to Ship STS
3. Pipeline to Ship PTS

There are several factors that need to be considered prior to deciding the most suitable transfer method. These include:

- Safety and Environmental Factors
- Regulations and Legislation
- Financial aspects
- Requirements of the End User (e.g. quantity and bunkering times)
- Time Constraints for bunkering operations
- Port infrastructure, layout and arrangement
- LNG supply in the local area
- BOG management

The following sections gives a general description of each method and of the technology that is typically implemented to make the LNG bunkering transfer possible in operations at Ports, while [B2 C 2.4] collects the recommended requirements that components of every party should be met.

2.1. Truck to Ship (TTS)

Most LNG bunkering operations to date have been carried out by LNG bunkering trucks. Typically, LNG is delivered to the receiving vessel by a 50 m^3 to 100 m^3 LNG road tanker parked on the quayside. The LNG is transferred through a flexible hose at a flowrate of between 40 m^3/hr. to 60 m^3/hr.

Figure 1 shows the Cruise Ship “Aida Prima” connected to an LNG Road Tanker in the Port of Hamburg. The “Aida Prima” is designed to run on LNG only while in Port, a process known as ‘LNG fuelling’.

Figure 2.1 “Aida Prima” Cruise ship connected to an LNG Road Tanker in the Port of Hamburg

For larger vessels, simultaneous LNG bunkering using multiple trucks connected to a common manifold is employed to maximize the transfer capacity and reduce the total LNG bunkering time to a minimum (MTTS).

LNG bunkering by truck offers a flexible solution given its small size allowing bunkering at different port locations.

RSOs requirements for larger LNG bunker capacities has led to the adoption of two TTS systems both in operation in ports today: Direct TTS and Multi TTS.

Direct TTS

Direct TTS is based on the local LNG truck market capacity to transport bunker fuel into the port quay areas.

Direct TTS operations are characterized by the relative simplicity and absence of specific supporting equipment with the mobile truck arriving at a predetermined area at the quay very close to the berthed ship’s bunkering station (refer to Figure 2.2). The truck usually provides own hoses that are connected to the truck and the receiving ship’s bunker manifold. The hoses are normally laid on the ground unsupported and only supported by the ship’s bunkering station overhead crane. The truck uses its own pump for LNG transfer to the ship’s tanks. There is no ability for vapor return to truck system.

Figure 2.2 Example of single TTS bunkering on Baleria Ro-Pax

MTTS (Multi-truck-to-ship)

Multi TTS require a purpose-built LNG bunkering system installed on a specific quay area in the proximity of the berths. Several bunkering station positions connected to a common header allow for the simultaneous connection of several trucks (see Figure 2.3). Instead of bunker trucks, connection to standard LNG containers can be provided. The bunkering system includes its own pumps to transfer bunker fuel to ships manifold either via hose or a fixed arm offloading system. There is no ability of vapor return to the trucks, however, a purposely designed tank to enable vapor return flow could be provided as part of the bunkering system utilities.

Figure 2.3 - Example MTTS bunkering on containership (Jacksonville Port U.S.)

Containerised LNG tanks used as fuel tanks on board ships (CTS)

The transferring of LNG is performed onboard and within the receiving ship by containers pre-loaded with LNG that constitute a complete fuelling package. Typically, each such container would be connected to three different piping systems onboard the receiving ship: the LNG fuelling line to the LNG-fuelled engines, piping to the vent mast for the pressure relief valves (PRV) of each container and the inert gas system of the receiving ship.

As detailed on the IACS LNG Bunkering Guidelines, this method of bunkering could be considered equivalent to using portable LNG tanks, its requirements addressed by the IMO IGF Code sections 18.4.6.3. and 18.4.6.4., that are placed on board a gas-fuelled ship for the purpose of becoming the ship's LNG fuel bunker tanks.

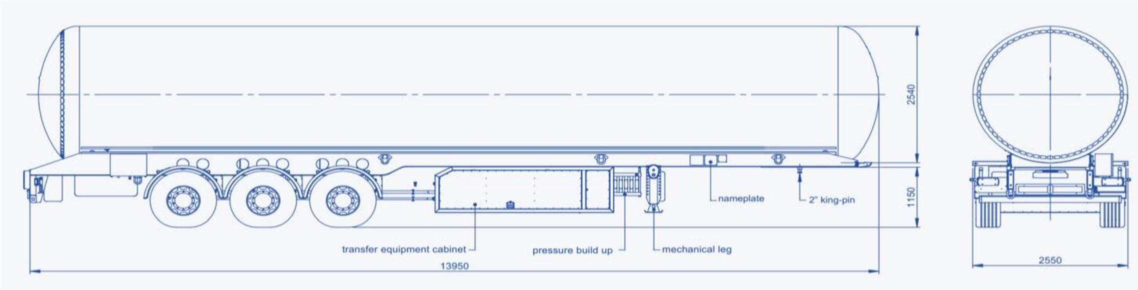
2.1.1. Cargo Tanks used on trucks

There are two unique types of LNG cargo tanks used in trucks as follows:

- **Single-wall pressure vessel** design made of stainless steel with some type of polyurethane foam insulation and protective stainless-steel cover.
- **Double-wall pressure vessel**, with inner wall of stainless-steel design using vacuum-insulation as primary insulation and multi-layer foil or perlite as secondary insulation. The vacuum insulation and perlite/ML insulation is then held by a carbon steel outer shell design. Double-wall pressure vessel are considered more reliable and resilient to withstand minor defects and are therefore recommended for enhanced safety considerations.

A bulk LNG transport truck incorporates a tank system which effectively combines two tanks similar to a Type C tank. The inner tank may be stainless steel or aluminium; the outer tank should be steel (typically carbon or stainless steel). The tank can be vacuum insulated (vacuum space between the inner and outer tank) or this space filled with an insulating material such as multi-layer super insulation ("MLI" or "SI"), fiberglass, or, on older units, expanded perlite. This keeps the LNG at storage cryogenic temperature and the system pressure low for a long enough period to transport and unload the fuel, typically no more than 7-10 days. The double layering of metal tanks and structural supports make the overall tank extremely robust to physical damage and the effects of external fire.

Typically, LNG truck tanks built to cryogenic liquid standards (LNG, Liquid Nitrogen and Liquid Oxygen), have a design pressure of approximately 6.9 bar and normally operate at pressures of less than 4.8 bar. Should the tank pressure exceed this level, a pressure release valve (PRV) will safely release gas through an outlet pipe to the atmosphere. Venting of LNG trailers is rare in normal operations since the hold time of a trailer vastly exceeds the normal delivery time of one day (the holding time of a trailer in normal operational conditions and as per originally designed is approximately 20 to 30 days), so that venting is just considered in an emergency situation. Redundancy is built into this pressure relief system through a secondary pressure release device with a pressure limit normally set 30-50% above the primary device pressure limit and well within tank safety design standards. Typical LNG trailer truck tank specification requirements are shown in Figure 2.4.



GENERAL FEATURES

- Type: Cylindrical, chassis-mounted.
- Nominal volume: 58 m³.
- Maximum authorised mass (MAM): 44 mt.
- Section: Circular.
- External tank diameter 2,550 mm.
- Total tank length* 13,800 mm.
- Total vehicle length* 14,000 mm.
- Tractor head tare* 7.5 mt.
- Semitrailer tare* 12.5 mt.
- Load capacity 95%* 23 mt (a 3 bar).
- Load capacity 88%* 21 mt (a 0 bar).
- Load capacity (MAM 44 mt)* 24 mt.

DESIGN

- TPED 2010/35/EU approved, compliant with directive 2014/103/EU, IMDG (short distances).
- Design code: UNE-EN-13530.
- ADR transport regulations.
- Classes 2.
- Products to be transported: LNG (UN 1972), methane (UN 1972), ethane (UN 1961), ethylene (UN 1038), nitrogen (UN 1977).
- Maximum operating pressure: 3 bar.
- Test pressure 5.2 bar.
- Design temperature: -196ºC + 50ºC.
- Material inner tank in austenitic stainless steel.
- Thermal insulation: Multilayer insulation + vacuum.

Figure 2.4 Example Specification of LNG Trailer Truck. Fuente: Lapesa

2.1.2. LNG Transferring system

The LNG bunkering truck would be fitted with a cold box containing the elements of the LNG transfer system such as piping, valves, including emergency shutdown devices, and the corresponding gauges. Typical arrangement is shown on Figure 2.5.

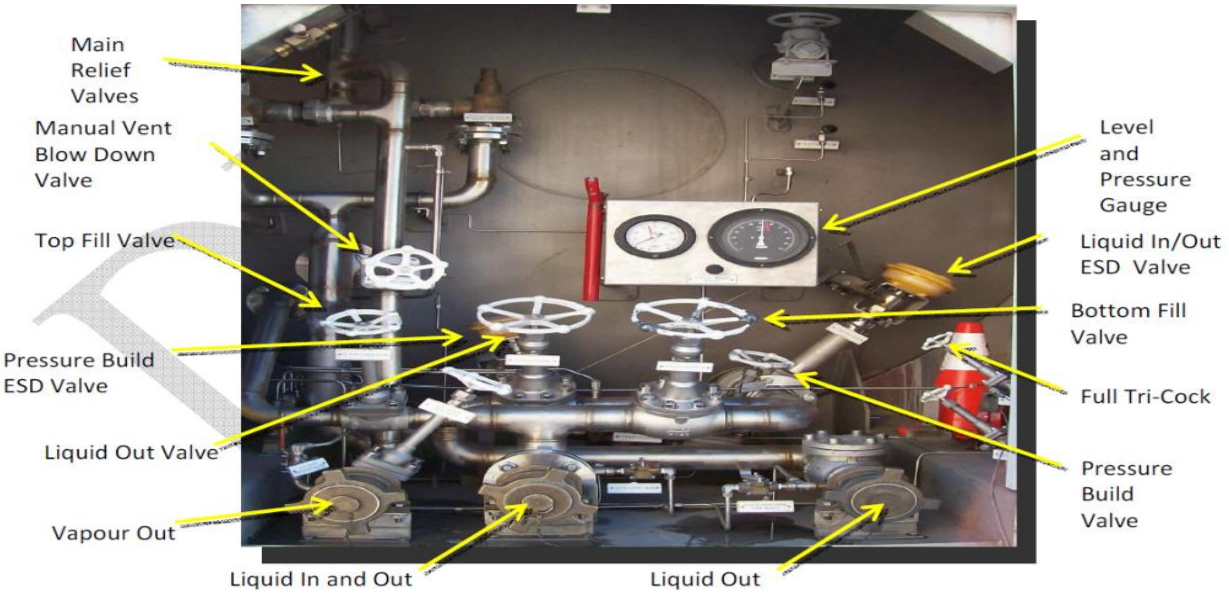


Figure 2.5 LNG Transfer System in the LNG Bunkering Truck Cold Box

2.2. Ship to Ship (STS)

LNG is delivered to the receiving vessel by an LNG bunker vessel (LBV) or LNG Bunkering Barge (LBB), using a loading arm or flexible hose. Generally, the range of LNG volumes transferred are between 100 m^3 and 18,600 m^3 - a recent example being the new CMA-CGM container ships that are bunkering up to 16.000 m^3- at flowrates of between 500 m^3/hr. and 1000 m^3/hr.

Figure 2.6 Shell's LBV "Coral Methane" alongside an LNG fueled cruise ship.

LNG bunkering involves purposely built LNG Bunkering Vessels (LBV) or LNG Bunkering Barges (LBB) or Small LNG Ships fitted with large LNG cargo tanks of type B, C or membrane design.

LNG Bunkering Vessels have the distinct advantage of bunkering large sea going ships, given their capacity ranging from 500 – 20,000 m^3 and their ability to manoeuvre and position close to the gas fuelled vessel at most berthing locations.

2.2.1. Cargo tanks used on bunkering vessels or barges

The containment system is a critical aspect of small-scale LNG carrier design and the return on investment that the ship is able to achieve.

The *International Maritime Organization (IMO)* categorizes LNG tanks on board ships, both for LNG bunkering vessels / barges and for LNG Receiving Vessels, as well as for Gas Carrier Ships, as shown in Figure 2.7.

There are three types of LNG cargo tanks employed by LNG bunkering vessels as follows:

- Type C Tanks
- Membrane Tanks
- Type B Tanks (Prismatic and Spherical designs)

For a better understanding of this classification, the image below illustrates the scheme used and an example of a real-world application.

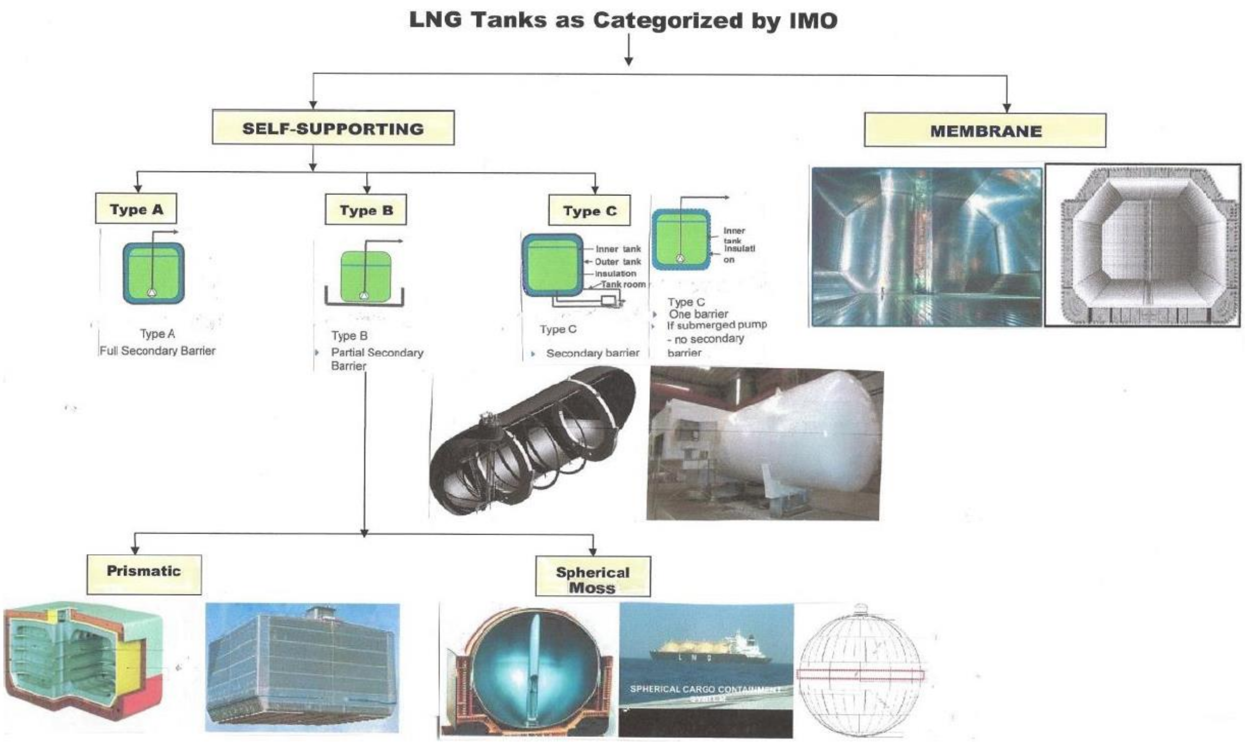


Figure 2.7 IMO categories for tanks carrying LNG on board ships.

Type C Tanks

Most LNG bunker storage tanks are independent type C tanks (pressure vessels) designed, constructed, and tested in accordance with the requirements of the IGC Code. The LNG storage tank is normally provided with a double wall arrangement and vacuum insulated. The annulus space between the inner and the outer wall is also filled with perlite or other means of insulation, which provides an alternative form of insulation in the event of vacuum deterioration.

Type C tanks are containment systems with a robust design, the design of the tank scantlings and tank support can withstand LNG sloshing at any filling level, flooding of the tank hold space and onerous acceleration forces because of collision and grounding. They are typically of spherical, cylindrical or bilobed pressure vessel design and are fabricated from 9% nickel carbon steel; for LNG cargoes these are fully or semi-pressurized (with the pressure maintained at around 5 bar). To minimize the boil-off gas rate the larger tanks are usually insulated with polyurethane foam or vacuum insulated for smaller volume tanks.

One of the advantages of the Type C tank is that they can sustain a degree of internal pressure build-up due to boil-off gas. These tanks are designed and constructed in line with pressure vessel requirements in the IGC code. Unlike most LNG cargo tanks; these type C tanks are not fitted with secondary barriers owing to their conservative design requirements, construction practices and excellent safety record.

Figure 2.8 Type C tanks on top the upper deck of a Gas Carrier at sea

Membrane Tanks (not self-supported)

The LNG membrane tank is seeing adoption in LNG bunkering vessels and large gas fuelled ships owing to its high volumetric capacities and its ability to conform to the geometry and form of the vessel's inner hull. An LNG membrane tank is supported by the ship's inner hull (i.e. unlike a type C tank, it is not self-supporting) and consists of a very thin layer or membrane (about 0.7 -1.5 mm thick depending on the tank variant) that derives its support from the adjacent hull structure via the inter-connecting insulating material and its secondary barrier.

The membrane is designed in such a way that thermal expansion or contraction, including high frequency loading is compensated for without undue stressing of the membrane.

Both IGC and IGF codes require the design vapour pressure of membrane tanks to be at 0.25 barg or less. Furthermore, due to the intricate design and construction of the membrane and insulation system, the IGC and IGF codes require a full secondary barrier to ensure the integrity of the tank in the event of a primary barrier leakage.

Membrane systems store the LNG at near to atmospheric pressure and at a temperature of -163°C. The technology is synonymous with GTT, a cryogenic technology manufacture from Paris, France, whose containments systems are widely used in the LNG Carrier Ships (LNGC).

Figure 2.9 Clean Jacksonville barge with a 2.200 m³ membrane tank

Type B Tanks (Prismatic and Spherical Designs)

Type B tanks share some similarities with both membrane (in terms of prismatic geometry and form factor) and type C tanks (in terms of its structural independence from the surrounding hull).

Fundamentally a type B tank is an independent tank designed using model tests, refined analytical software tools and analysis methods resulting in improved accuracy of stress levels, fatigue life and crack propagation characteristics.

There are two types of type B tanks: the prismatic type -constructed of flat surfaces closely aligning with the shape and form of the surrounding hull structure, then the spherical tanks of moss design which has been used in the LNG carrier trade over several decades.

For LNG bunkering, LBV, LBB and LNG gas-fuelled ships, prismatic type B tanks provide the benefit of maximizing ship hull volumetric efficiency. Another geometric benefit over the spherical type is that the entire cargo tank is placed beneath a flat upper deck, although the design vapour pressure is limited to 0.7 bar-g. The improved engineering analyses and tools resulting in enhanced design factors and failure understanding make possible for type B tanks to require only a partial secondary barrier in the form of a ‘drip tray’.

At time of writing, there are no real examples of LNG fuelled or bunkering vessels with Type-B tanks.

2.2.2. LNG Transferring system

Generally, LNG is transferred to the receiving vessel via a loading arm arrangement or flexible hose. They should be designed in accordance with ISO/TS 18683 and suitable for use to transfer products at a minimum temperature of -196°C.

Loading Arms

Loading arms are rigidly constructed with mechanical articulated joints to allow the required movement to connect to the receiver ship. They can offer many benefits, including assisted actuation with hydraulic or pneumatic systems as well as easier handling and connection. The Figure 2.10 below shows a typical loading arm manufactured by FMC Technologies.

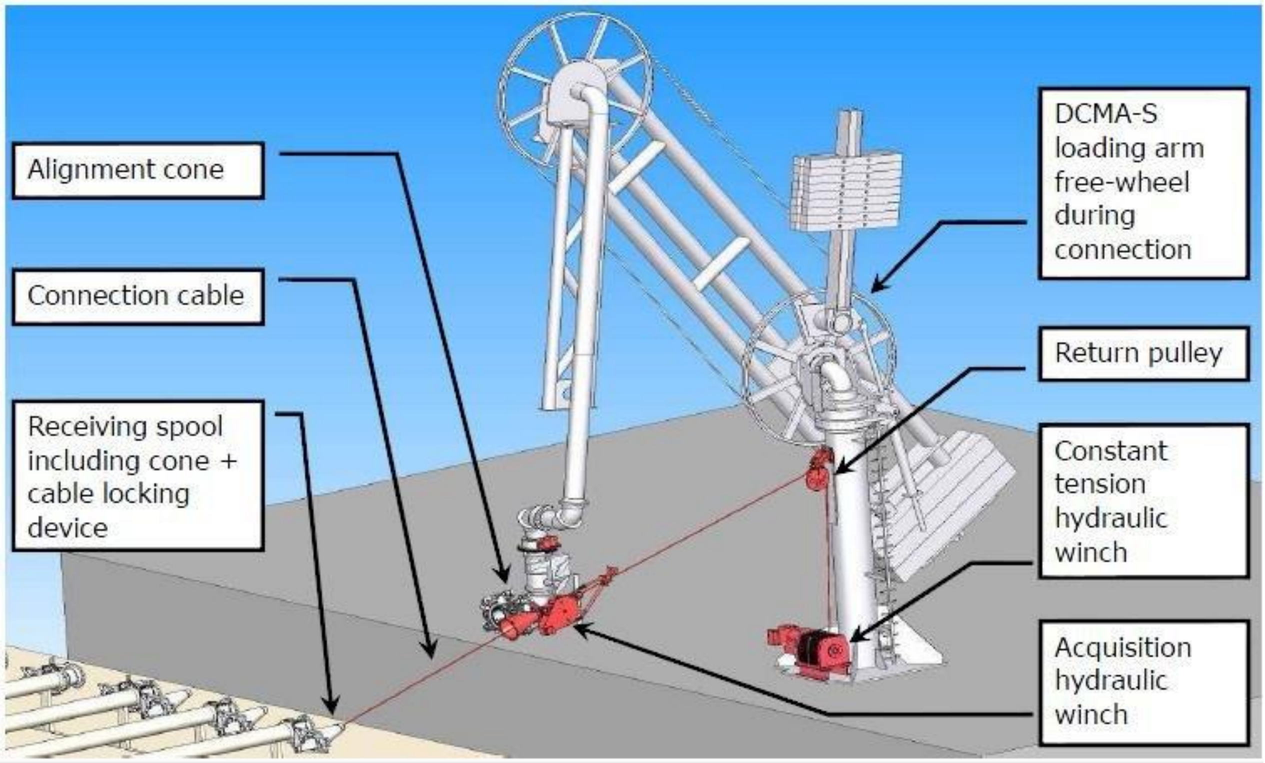


Figure 2.10 Typical LNG Loading Arm and main parts

Table 2.1 provides a summary of current or under construction LNG fuel systems for typical type of vessels operating at Mediterranean ports. The intention is to show case the positions of the LNG receiving bunker stations in order to enable provision of an appropriately positioned STS and/or PTS system and marine mooring facilities for such a jetty or for equivalent arrangements when provided onboard an LBB/LBV.

Table 2.1 RSO Ship Types LNG bunkering station location

Ship Type	LNG fuel tanks (m3) and Type	Typical LOA (m)	Bunker Station position (m)	Bunker Station height (m) from waterline
Bunker Barge	2,000 Type-C	65	Cargo manifold mid-ship	7 m
Tugs	25 - 100 Type C	20-60	On main deck close to bridge	4 m
Feeder Containership	6,000-7,000 Type C	115	Cargo manifold mid-ship	12 m
Car carrier	min 5,000 based on existing trade routes IMO Type B (SPB) or Type C	225	40m from stern	6 m
UltraLarge Containership	10,000 IMO Type B proposed	200	40m from stern	6 m
Cruise ship	3,000-4,000 Type C	300	55m from stern	5 m

Loading arms are normally installed at fixed locations and can offer the possibility to transfer large volumes of LNG at high speed. However, there are loading arms also seen installed on ships, for STS transfer methods, for example arms installed on LBVs so that LNG could be delivered to a wider range of RVs; such LBVs have adopted loading arms in order to handle the transfer of LNG safely for a wide range of vertical distances between the LBV and RSO's manifolds.

Whether the loading arms are part of a fixed land installation or are located onboard an LBV, the bunkering system they form part of should be capable for the connection and safe transfer of LNG at a range of defined flow rates, within a set of pressure and temperature criteria without any adverse effects or leakage.

The specification of such STS bunkering system with loading arm should address the following:

- System compatibility between the jetty/receiving vessel (BFO and RSO);
- Compatible with LNG receiving manifold design including removable spool pieces and connections;
- Safety systems compatibility between BFO and RSO;
- Impact of ship motions and environmental conditions (swell, wind speed, sea state, etc.) should be considered;
- Loading arm compatibility with Pre-bunkering cool-down and post-bunkering purging and inerting processes;
- Compatibility with LNG bunker transfer rate during bunker start-up, full load and topping-off operations;
- Compatibility with LNG fuel tank pressure and level control; and,

Compatibility with the maximum operational pressure and temperature range allowed during the bunkering operation.

LNG bunkering cryogenic hoses

Flexible hoses have been used successfully for LNG transfer operations for many years now. They are usually constructed of composite multi-layer thermoplastics and should be designed to suitable recognised standards, such as EN 1474-2, EN 1474-3, EN 12434 or BS 4089. It is important that they are designed and used correctly, for example, suitably handled and supported throughout the connection, bunkering and disconnection process.

Hoses should be permanently marked with the following information:

Hose serial number
Internal diameter of the hose
Overall weight of complete hose
Date of manufacture
Date of proof pressure testing
Certifying Authority Approval
The maximum working pressures
The maximum flow rates
The maximum and minimum allowable working temperature range

Whether using a loading arm or flexible hose arrangement, it is important to consider the following factors:

Differential movement between the bunker vessel and receiving vessel
ESD system functionality
Electrical insulation
Pressure relief devices to protect against over pressurisation in the event they contain a trapped liquid inventory
End connections
Facility to drain and purge the contents

Aerial Flexible Hoses

From an operational perspective the maximum hose size will be governed by the capabilities of the lifting equipment and the bunker manifold construction on-board the receiving vessel.

In determining the length of the hoses to be used the following should be considered:

Maximum allowable bend radius of the hose.
Horizontal distance between the vessels, as governed by the fender diameter.
Distance between bunker manifold of receiving ship relative to and the supporting arm/crane reach from the bunker tanker.
Vertical and horizontal vessel movement.
Any other special design features related to the bunker tanker and bunkering system to be utilised.
Relative change in freeboard between the vessels.

The fuel transfer equipment should be supported by suitable means to prevent excessive load on manifold fittings in accordance with the minimum size of the OCIMF manifold guidelines.

The flexible cryogenic hoses are typically made of the following principal layers:

Inner wire: Stainless Steel 316
Lining: Polyester fabrics and films
Outer cover: Polyamide
Outer wire: Stainless steel 316

The design lifetime of the typical bunkering hose is 5 years.

The worst environmental conditions for which LNG transfer can be performed by the system are based on current LNG STS cargo transfer and lightering operations in a near shore sea environment which corresponds to sea state 4 (Hs<2.5m, T<9.5s). A common value adopted for bunkering operations at port is sea state 2-3 (Hs<1m).

Multi- LNG STS hoses are available in sizes from 1”- 8” diameter and lengths up to 30.0m, 10” and 12” up to 20.0m and 16” up to 15.0m.

The maximum flow rate tested on an LNG 8” hose is 1,500 m³/h (Gutteling). Manufacturer’s recommendation is to keep flow rate under or equal to 1,200 m³/h.

Similarly, manufacturer’s recommendations for maximum flow rate is 1,750 m³/h for the 10” hoses and 2,500 m³/h for the 12” hoses.

Full technical characteristics of the hoses are listed in the table below:

Table 2.2 Hose Technical Characteristics (Gutteling)

Bore Diameter	**Max. Work. Pressure**	**Burst Pressure (1)**	**Pressure losses (2)**	**Min bend radius (1)**	**Elongation Twist**		**Weight**	**Available lengths**
Inches	*Bar*	*Bar*	*Bar/m*	*Inches*	*%*	*º/mtr*	*Kg/m*	*m*
3	10.5	180	0.30		6	<1	09.0	30
6	10.5	180	0.30	25.0	6	<1	12.6	30
8	10.5	180	0.20	35.8	6	<1	20.1	30
10	10.5	145	0.20	59.0	6	<1	23.9	25
12	10.5	125	0.20	78.7	5	<1	36.0	20
16	20.0	105	0.10	98.9	5	<1	47.0	15

(1) Performed at cryogenic conditions

(2) Performed at cryogenic conditions and at maximum allowable flow speed of 14/ms

Depending on the bunker station location and lay-out, suitable equipment (e.g. saddles, lifting lugs) should be employed to ensure the minimum hose bending radius is not exceeded, and to assist in the support of the hose throughout the transfer operation.

All supporting equipment may be integral to the load restraint system preventing excessive axial and torsional loads on the bunker hose end fittings. Their design load and safety of layout must be considered along with their ability to prevent chafing of the hose(s) and mitigation to avoid damage within the bunker station during an event of ERS activation and hose disconnection. Their design should ensure electrical isolation is maintained between the hose and the ship’s structure.

Floating cryogenic hoses

It is noted a floating hose system has been designed by SBM and certified as since 2011. Since then there were also additional systems provided by Trelleborg and others, based on similar configurations.

The floating hose design comprises of an outer marine hose with an inner composite LNG hose. The space between these two hoses is filled with insulating materials which have excellent properties over the full range of ambient to cryogenic temperatures. A typical hose is designed as an assembly of 35-feet sections in order to facilitate manufacturing, transport and change out.

2.3. Pipeline To Ship (PTS)

LNG is delivered to the receiving vessel directly from the terminal or small storage facility via a pipeline. Connection to the receiving vessel is either by a loading arm or flexible hose. The specification of hoses detailed in section 2.2.2. above is considered generic and can be applied to hoses used on PTS transfers. Typical LNG volumes stored in dedicated bunkering storage facilities are between 500 m³ and 20,000 m³ which can be transferred at flowrates of between 1,000 m³/h and 2,000 m³/h.

The PTS bunkering system should be capable for the connection and safe transfer of LNG at a range of defined flow rates, within a set of pressures and temperatures criteria without any adverse effects or leakage.

The specification of the PTS bunkering system to address the following:

- System compatibility between the jetty/receiving vessel (BFO and RSO);
- LNG receiving manifold design including removable spool pieces and connections.
- Safety systems compatibility between BFO and RSO.
- Impact of ship motions and environmental conditions (swell, wind speed, sea state, etc.);
- Pre-bunkering cool-down post bunkering purging and inerting process.
- LNG bunker transfer rate during bunker start-up, full load and topping-off operations.
- LNG fuel tank pressure and level control; and,
- Maximum operational pressure and temperature range allowed during the bunkering operation.

As per hoses specifications, the system considerations are considered generic and equally applicable to other LNG bunkering transfer methods. Specific system considerations are included in the bunkering checklist that are recommended to be adopted for the chosen bunkering transfer method; see section 3.4.

2.3.1. Cargo tanks used for PTS LNG Bunkering at Ports

Land-based LNG storage tanks have been used by LNG export and import terminals for over 60 years, underpinning the global trade of LNG. In general, there are three main tank geometries, influenced by the storage capacity and the tank design (operating) pressure, being the three main types:

- **Flat bottom tank**. The largest type with a capacity between **2,000 – 250,000 m³** operating close to atmospheric pressure.

- **Bullet tank**. Modular pressure vessels having a range of capacities as small as **100 m³ to 1,000 m³**. Their robust construction (i.e. designed, constructed and tested to pressure vessel standards) allows higher operating pressures.

- **Spherical tank**. Mid-range volume capacity handling between **1,000 – 8,000 m³** of volume. Its spherical geometry allows for tolerance of higher operating pressures.

- 

The ability of fixed storage tanks to minimize the risk of LNG leakage including large loss of containment events (LOC) is represented by the integrity level of the installation. Briefly each integrity level can be differentiated as follows:

- **Single integrity level tank**. In the event of leakage allows uncontrolled release of LNG into the environment following by uncontrolled vapour release (gas cloud) onsite. This is typical of a bullet tank installation given their relatively small volume but also the conservative factors of safety used in the tank design.
- **Double integrity level tank**. In case of leakage, LNG release is mitigated by a partial secondary containment normally via a concrete pit or dike – thus allowing a controlled release of the gas vapour to environment (i.e. the dike limits the travel distance of the gas cloud).
- **Full integrity level tank**. This design incorporates a full gas tight secondary barrier such that leakage from the primary barrier does not result in the release of LNG into the environment. The annulus space (i.e. between the primary and secondary barrier) is vented allowing a controlled release of gas vapour into the atmosphere.

2.3.2. LNG transfer systems

It is noted that existing LNG terminals have been constructed in order to provide LNG loading/unloading operations of LNG carriers (LNGCs) operating standard 16-inch LNG cargo manifolds. The LNG loading/unloading arms, the height of the receiving ship's manifolds, cargo pumping and transfer flows, the size and moorings of the jetty are intended to service deep water trading LNGCs.

For such Terminals, and for the purposes of bunkering operations, a smaller jetty equipped with smaller and lower-reach arms and smaller pumping arrangements is normally required.

The PTS system would need to be able to typically serve the following arrangements:

Typical bunker barge loading manifold is at mid-ships on main deck at a height 5-6m from waterline.

Car carrier and Ro-Pax vessels of typical length 130-190 m, draught 5-6 m, has bunkering station door positioned 6m above water line and approximately 15m distance from the stern. Nevertheless, these values can range from 3m to 9m for bunkering station height position and 15m – 70m for distance to the stern depending on the size of the vessel.

A current container ship conversion is approximately 200m length and has bunkering station on main deck approximately 40m from the stern.

Table 2.1 in section 2.2.2. provides a summary of current or under construction LNG fuel systems for typical type of vessels operating at Mediterranean ports. The intention is to show case the positions of the LNG receiving bunker stations in order to enable provision of an appropriately positioned PTS system and marine mooring facilities for such a jetty.

For loading arms that are part of a fixed land installation, the bunkering system they form part of should be capable for the connection and safe transfer of LNG at a range of defined flow rates, within a set of pressures and temperatures criteria without any adverse effects or leakage.

The specification of such PTS/STS bunkering system with loading arm should address the following:

System compatibility between the jetty/receiving vessel (BFO and RSO);
Compatible with LNG receiving manifold design including removable spool pieces and connections;
Safety systems compatibility between BFO and RSO;
Impact of ship motions and environmental conditions (swell, wind speed, sea state, etc.); should be considered;
Loading arm compatibility with Pre-bunkering cool-down and Post-bunkering purging and inerting processes;
Compatibility with LNG bunker transfer rate during bunker start-up, full load and topping-off operations;
Compatibility with LNG fuel tank pressure and level control; and,
Compatibility with the maximum operational pressure and temperature range allowed during the bunkering operation.

A PTS bunkering system may adopt one of the following typical design specifications:

A system incorporating two (2) rigid articulating loading arms:
one (1) arm (cryogenic) designed to load liquid LNG and
one (1) arm (non-cryogenic) enabling vapour return to the terminal in order to ensure that Boil Off Gas (BOG) management takes place during LNG transfer.
A system incorporating two (2) articulating arms each supporting a composite cryogenic hose.
One arm/hose will undertake LNG loading and the other arm/hose will enable vapour return.
A system incorporating two (2) composite cryogenic hoses which are lifted and supported when they are connected to the RVs' cargo manifolds by a small crane pedestal.

2.4. Safety components and critical Equipment

The following is recommended for LNG technology related to equipment that is considered critical for any LNG bunkering transfer, pumping, emergency operation and electrical isolation while bunkering LNG.

2.4.1. LNG transfer equipment and components

The selection of transfer equipment to be employed in bunkering operations requires considerable care.

Prior to the equipment being deployed, all elements of the bunkering system including the loadings imposed on manifold working platforms, presentation flange, hoses and their support arrangements, "Y" reducers and any emergency release couplings and their associated operating systems must be fully evaluated, certified and shown to be fit for purpose for this application.

To achieve this technology qualification a process like the one undertaken by Classification/Certification should be used for the approval of the bunkering system and its integration on-board an LBB or LBV.

Where bunkering marine offloading arms or hoses are utilized, these may be supplied by the manufacturer and be fitted on-board the bunker vessel by the BFO. Continuous control and monitoring of the integrity and safety of the bunkering system in operation is essential and it is the prime responsibility of the BFO.

For systems employing cryogenic hoses or a combination of piping/hoses, specification and maintenance requirements should be complied with and should include the following as a minimum:

- Design characteristics – the use of hoses with leak before failure mode.
- Hose certificate from Certifying Authority must accompany each hose.
- In-Service Testing procedures developed in line with manufacturer's recommendations, or as necessary to prove the integrity of the hose prior to use. Records of testing and inspection must be maintained.
- Storage of hoses – hoses must be stored as per manufacturer's recommendations and in such a manner to minimize the possibility of mechanical damage or the entrapment of moisture.

Typical LNG supply transfer system for an LBB/LBV may be configured as follows:

- Rigid marine articulating arm system incorporating Quick Connect /Disconnect Coupler (QC/DC) and ERS system.
- Fully supported and protected LNG flexible hose system with ESD link, QC/DC and ERS. A dry break away coupling combining the functions of a QC/DC and ERS or any similar connection and safe release devices will be acceptable if it complies with the principles of EN1474-1/ISO 16904 and approved by a classification society.
- The flexible hose is to comply with EN 1474-2. Any deviation from EN 1474-2 is to be acceptable to the Classification Society.
- Any LNG marine transfer arm assembly is to comply with EN1474-1 /ISO 16904. The assembly is to be made of the following components:
- Quick Connect Disconnect Coupler (QC/DC) should comply with EN1474-1 /ISO 16904.
- Emergency Release System (ERS) complying with EN1474-1,3 /ISO 16904.
- A linked ESD system should comply with ISO20519:2017. Any deviation is to be acceptable to the Classification Society.

The fuel transfer equipment should be supported by suitable means to prevent excessive load on manifold fittings in accordance with the minimum size of the OCIMF manifold guidelines.

Depending on the RSO's bunker station location and lay-out suitable equipment (e.g. saddles, lifting lugs) should be employed to ensure the minimum hose bending radius is not exceeded, and to assist in the support of the hose throughout the transfer operation.

All supporting equipment may be integral to the load restraint system preventing excessive axial and torsional loads on the bunker hose end fittings. Their design load and safety of layout must be considered along with their ability to prevent chafing of the hose(s) and mitigation to avoid damage within the bunker station during an event of Emergency Release System (ERS) activation and hose disconnection. Their design should ensure electrical isolation is maintained between the hose and the ship's structure.

LNG Pumps for LNG Bunkering

- Submerged pumps

  Low pressure submerged LNG centrifugal pumps with horizontal impellers are typically installed in the lowest point of the LNG storage tank (i.e. the LNG tank pump well/sump). In addition to transferring LNG to a receiving tank on the LNG fuelled ship, these pumps are also used for recirculation to avoid stratification and roll-over hazards in large, fixed LNG storage tanks.

- External LNG pumps

  Skid mounted centrifugal pumps are designed to transfer LNG between pressurised tanks (i.e. between two type C tanks with elevated operating pressures) at high flow rates typically more than 100 m^3/hr. They are used for multiple truck LNG bunkering arrangement, where the skid provides the local control panel including manifold fittings (t-connectors, y connectors) to accommodate the flange connections of a receiving gas fuelled ship.

LNG Pressure Build-up Unit

A pressure build-up unit PBU is a heat exchanger typically of shell and tube design that vaporizes LNG collected from the bottom of the LNG tank to increase the tank's operating pressure. The resulting vapour is sent to the top of the tank (the vapour space) to naturally increase the tank pressure. Once a certain tank pressure is achieved (i.e. based on the desired flow rate), bunkering is commenced and the PBU acts as a flow regulator by managing the vapour generation rate.

LNG Cryogenic Hose

LNG bunkering hoses are composite multi-layer thermoplastic types, designed, constructed and tested in line with the requirements of EN 1474-2 - Design and testing of marine transfer systems (Design and testing of transfer hoses). These hoses connect either end of the bunkering manifold (bunkering facility and receiving gas fuelled ship) with dry connect, disconnect couplings that are drip free, allowing the connection to be made without any LNG leakage.

Cryogenic hoses and its supporting system play a critical role in the efficiency (i.e. time to complete the LNG bunkering) and safety (i.e. prevention of leakages, large and small). For hoses to be effective and safe, certain bunkering parameters and information should be made available during the submission:

- Maximum allowable bend radius of the hose.
- Horizontal distance between the gas fuelled vessel and LNG supplier.
- Distance between bunker manifold of receiving ship relative to and the supporting arm, crane (if fitted) reach from the bunker supplier.

- Vertical and horizontal vessel movement.
- Relative change in freeboard between the vessels (ship to ship only).
- Details of the hose supports (e.g. saddles, lifting lugs, etc.) that prevents/mitigates excessive load on either manifold in accordance with the OCIMF manifold design recommendations.

LNG Dry Connect, Disconnect Couplings

A dry connect, disconnect coupling (also called dry break coupling) is a mechanical device which permits the quick connection and disconnection of the LNG hose between the bunker facility and the manifold of the receiving vessel in a safe manner without employing bolts. The coupling consists of a nozzle part and a receptacle part. The nozzle part of the dry coupling is typically mounted on the hose end of the bunker facility, which permits quick connection and disconnection to the receiving vessel in a safe manner. The nozzle part has an internal valve to seal the nozzle end upon disconnection. The receptacle part of the coupling is mounted to the manifold flange of the receiving vessel. Similarly, it includes an internal valve to seal the receptacle end upon disconnection. The design, construction and testing of dry connect, disconnect couplings should comply with the requirements of ISO 21593:2019.

2.4.2. LNG Boil-Off Gas Management Equipment

Boil-off gas generated by heat ingress and primarily by the vapour returning from a warm LNG tank being bunkered require continuous management or removal from the LNG storage tank. Although the BOG return from bunkering operations is transient, this can be a substantial capacity given the size of the tank being bunkered, its saturated temperature and filling level prior to bunkering.

Re-Condensers (Liquefaction of Boil Off Gas)

Re-condensers are specialized shell and tube heat exchangers that form part of the boil-off gas management system of large LNG bunkering facilities (i.e. fixed storage tanks and bunkering vessels). A re-condenser works by cooling the boil-off gas (vapour) using a liquefied nitrogen or similar refrigerant. Having a large re-condenser is beneficial for bunkering large gas fuelled ships but also in managing the natural boil-off from large LNG tanks.

Re-liquefaction System

There are three general types of re-liquefaction plants, distinguished by their capacity range but also physical size (skid footprint).

- Cascade Liquefaction Plants

Operated with 3 separate refrigeration loops that can be used sequentially or individually to liquefy the natural gas vapour. Each refrigeration loop is operated by a different fluid (i.e. methane, propane, ethylene) allowing a wide range of flexibility in handling different volumes and saturated conditions on incoming BOG. Given the large scale and high costs of investing in 3 refrigerant loops, this type of liquefaction plant is more suitable for larger LNG bunkering providers (i.e. Fixed land-based storage tanks with thousand cubic meter capacities).

- Mixed Refrigerant Plants

In this type of liquefaction system, BOG is cooled by a single refrigeration circuit that employs a blend of refrigerants i.e. normally some form of light refrigerant such as methane in addition to nitrogen. The rate of cooling the BOG is then controlled by a combination of optimization of the refrigerant mixture and the number of heat exchangers used (i.e. there are multiple parallel heat exchangers to accommodate capacity. Since this type of liquefaction plant employs a single refrigeration circuit, there are fewer compressors compared to the cascade system, minimizing the size and cost of the system.

- Turbo expander Plants

Turbo expanders are radial flow rotating machines that enables isentropic, adiabatic expansion - first via the guide vanes (inlet stator) that accelerates the gas vapour (BOG) unto the rotor which converts the kinetic speed of the gas vapour into energy that drives a compressor on the opposite end. It is the adiabatic expansion of the gas vapour that generates the cooling effect that condenses (liquefies) the gas.

BOG Gas Consumption and Disposal Systems

- Thermal Oxidisers, Gas Combustion Unit

A gas combustion unit (GCU) is utilized for burning excessive BOG but also during purging prior to commencing bunkering and just after completion of LNG line stripping (i.e. nitrogen purging prior to disconnection of bunkering). The combustion chamber of the GCU consists of burner(s) and igniter(s) that can operate under a wide range of BOG and nitrogen flow. It also has several parallel fans that provide air for combustion but also the cool down and dilution of combusted gases.

- Dual Fuel Machinery & Boilers

These are limited to LNG bunkering vessels only. Most if not all LNG bunkering barges and vessels are fitted with dual fuel machinery such as dual fuel (gas-diesel) engines and steam boilers. These machineries are used to manage the amount of boil-off gas in the cargo tank for propulsive and/or power generation. In the case of dual fuel boilers, some may have “dumping capability” where excess BOG is combusted by the burners and the resulting steam is sent to a “dump condenser” directly cooled by sea water pumps.

- LNG Supply and Return Vapour Piping

LNG transfer pipes on both the receiving ship and bunker vessel are fitted with double-wall vacuum insulated pipes that serves to reduce the boil-off gas during bunkering operations but also acts a secondary barrier in the event of LNG or vapour leakage.

2.4.3. Safety components, equipment and systems for LNG bunkering transfer and operation

Emergency Shutdown Valves (Remotely Operated Isolation Valves)

Emergency shutdown valves are typically of globe or gate valve design and are installed at several positions alongside the LNG transfer system of both bunkering facility and the receiving gas fuelled ship. As a minimum, there are two ESD valves for the purpose of isolating the bunkering piping system on either end (i.e. the bunkering facility and receiving ship). One position is close to the bunkering manifold and another serves to isolate the bunkering system from the gas fuel supply system of the ship. These remote operated valves are of the pneumatic or electro-hydraulic activation design.

Pressure Relief valves

Pressure relief valves are required by Classification Rules, IGF code (receiving vessel), IGC code (bunkering vessel), ISO 12614 (bunkering truck) and NFPA 59 (fixed storage tanks) to be fitted at the following locations:

- LNG tanks (receiving vessel and bunker facility side)

- Cargo holds (bunker vessels only)
- Inter-barrier spaces (bunker vessel and fixed storage tanks only)
- LNG piping (receiving vessel, bunker vessel and fixed storage tanks only)

For marine LNG tanks Class Rules, IGC code, IGF code requires at least two relief valves to be fitted to each tank. These relief valves are located on the vapour dome (or the highest point) of each LNG tank and their discharge piping arranged to terminate at the vent mast(s). Relief valves are designed, constructed, and tested to allow the maximum flow rate out of the tank under fire conditions. The correct sizing and installation of each valve is safety critical as it prevents a tank from becoming liquid full before the tank pressure rise lifts the valve. Membrane tanks and type B LNG tanks apply a 0.25 bar-g set pressure while type C tanks can set the relief pressure as high as 10 bar-g. Furthermore, type B and membrane tanks employ pilot operated type of relief valves while type C tanks may apply either spring loaded or pilot operated safety valves. The vent mast is arranged to discharge vertically, positioned at the highest practicable point of the vessel. It is fitted with a cowl arrangement that prevents the ingress of water and course mesh screens mitigate the ingress of foreign objects.

Furthermore, Class Rules, IGC and IGF codes require all sections of LNG piping that can be isolated (i.e. this means all LNG piping between two valves) to be fitted with a safety valve. This is to prevent over pressure in the piping and consequent leakage during inadvertent isolation as result of the liquid-vapour transition. But more importantly, this also protects against any potential fire affecting the LNG piping system.

Nitrogen System and Equipment (Nitrogen Generator)

Nitrogen is used in both normal operations and emergencies during bunkering operations. These operations include:

- LNG and vapour piping purging prior to commencement of bunkering and after the LNG topping up process.
- For the LNG bunker vessel and receiving ship, purging of the LNG piping and vapour piping in the event of an ESD, including an ESD event in the fuel gas system.
- Inter-barrier space environmental control of membrane and type B tanks.

Larger bunkering assets (fixed storage tanks and LNG vessels) are fitted with an inert gas generator (N2 generator). In addition to providing the necessary nitrogen during bunkering operations, a nitrogen generator can also be used to purged and empty an LNG tank. Smaller bunkering assets (LNG trucks, small bunkering barges) and receiving vessels typically carry nitrogen bottles (pressurized nitrogen) for purging.

Gas Detection

A fixed gas detection system is required by Class Rules, IGC and IGF codes to be fitted at the following positions:

Bunker station
Air locks
hazardous space ventilation exhaust
non-hazardous space ventilation air intakes
Double wall arrangements (annulus space)
Hold spaces (type B tanks only)
Inter-barrier spaces (membrane tanks only)

Each gas detector should be capable of detecting methane gas concentrations in both air and in inert spaces. Alarms will be initiated if the gas concentration in air exceeds 30% LFL (lower flammability limit). In the case of bunkering operation, automatic cessation via ESD will occur at 60% LFL.

Intrinsically safe electronics and electrical equipment in hazardous area

Classification of hazardous areas is necessary in order to establish the type of equipment that can be installed in the respective areas. The area of probability of a flammable gas mixture being present is categorized by the following three zones:

- Zone 0: An area in which flammable gas mixture is continuously present or is present for long periods
- Zone 1: An area in which there is likely to be a flammable gas mixture under normal operating conditions
- Zone 2: An area in which the presence of a flammable gas mixture is unlikely, but if such a mixture is present, it is likely to persist for only a short period.

It is not practical to eliminate the installation of electrical and electronic equipment in hazardous zones, therefore, hazardous area classification provides additional requirements on electrical equipment in order to avoid the explosion and fire dangers associated with the failure of normal equipment.

All electrical equipment used in these zones, whether fixed or portable installation, will be certified 'safe type equipment'. This will normally comprise the use of intrinsically safe, flame proof and pressurized enclosure type equipment. There are several different techniques that can be utilized to prevent electrical equipment causing explosions or fire in hazardous areas. These are summarized in the table below along with zones in which they can be used.

Table 2.3 Type of protection for electrical equipment located in hazardous zones

Symbol	Type of Protection	Suitable for use in Zone	Basic concept of protection
Ex d	Explosion (Flame) Proof	1,2	Contains the pressure, quench the flame
Ex e	Increased Safety	1,2	No sparking parts or hot surfaces
Ex ia	Intrinsically Safe	0,1,2	Limits the potential ignition energy and surface temperatures
Ex ib	Intrinsically Safe	1,2	
Ex m	Encapsulation	1,2	Keeps the flammable dust out
Ex n	Non Sparking	2	No sparking parts of hot surfaces
Ex o	Oil Immersed	2	Keeps the flammable gas out
Ex p	Pressurised	1,2	Keeps the flammable gas out
Ex q	Powder Filled	2	
Ex s	Special Protection	-	

Emergency Shutdown System (ESD)

Emergency Shutdown ESD Systems are widely used in high risk industrial applications, including the LNG shipping industry. They should provide a reliable, quick and safe shutdown of the LNG systems in response to an unplanned or emergency event.

The ESD system is considered part of the safety system that limits the damage, escalating effect of a single fault, failure during bunkering by manually or automatically stopping and carefully bringing the transfer operation to an isolated state.

It should be possible to activate an ESD from either ends of the bunkering transfer system, LNG bunkering vessel LBV/ barge LBB and LNG receiving vessel, with both ship's systems shutting down in unison. The LBV should be able to accommodate the different link ESD systems available. Typical link ESD systems are:

- Use of the Optical Fibre System, which comprises an optical fibre cable supplied from the LNG bunker tanker and linking the receiving vessel using a plugged socket located at the manifold.
- Pneumatic link that comprises a hose pressurized with air from ashore, which operates a pressure switch on board. Loss of air pressure by venting the line onshore or activation of solenoid valve on board or by hose parting will cause the pressure switch to operate and initiate ESD.
- Electric link relying on a 'Pyle National Eexd' flame proof connectors for connection of LNG supplier cable to receiving vessel interface. This system utilises a combination of digital 4-20 mA analogue signals.

There are usually two types of ESD, I and II. ESD I should result in the controlled shutdown of LNG bunker pumps, LNG pressurization equipment (e.g. if the LNG supplier uses a type-C tank and or a pressure build up unit) and the closure of the ESD valves (in less than 30 seconds). In addition to this an ESD II should result in the disconnection of the loading arm or flexible hose. This Emergency Release System (ERS) should be designed to minimize the release of LNG or natural gas and to protect the LNG transfer arm/hose through safe disconnection. The ERS design includes an emergency release coupling (ERC), consisting of interlocked isolation valves to minimize the LNG or natural gas release when the ERS is activated.

Initiation of the ERS should result in the simultaneous closing of the interlocked ERC isolation valves, followed by the ERC separation and the LNG transfer arm withdrawal from the receiving ship's manifold and structure. These actions are to be designed to prevent the LNG transfer arm from being damaged and the uncontrolled spill of LNG.

A Dry Quick Connect / Disconnect coupling (QC/DC) allow easy connection and disconnection without the use of manual and time-consuming connection (such as bolting). The design still includes stop valves at both ends to minimize the released inventory when it is activated.

The ESD (ESD I) system should be designed to safely stop and isolate the bunkering of LNG to the receiving ship and the return vapour to the bunker tanker. The ESD systems should comply with the minimum functional requirements in EN ISO 20519, paragraph 5.4.

Emergency Release System (ERS)

For safe bunkering operations, a single automatic and/or manually activated Emergency Release System (ERS) incorporating an Emergency Release Coupling (ERC), must be fitted to each transfer line.

An alternative to an ERS is the provision of a Quick Closing Dry Breakaway Coupling (QCDBC) capable to be mechanically operated under load.

The following ERS specification requirements should apply as a minimum:

- The ERS should be designed with a double seal and leak prevention arrangement with visual indication at the break point.
- The ERS operating system should retain sufficient stored power to release all transfer hoses in the event of ship blackout and the non-availability of ship provided utilities.
- The ERS design should be capable of operating and releasing the system, when exposed to the maximum theoretical fuel flow rate.
- The ERS system should be capable of manual activation from a remote safe location where the bunkering process is monitored on-board the bunker tanker.
- Step-by-step activation procedures are to be clearly posted at the ERS operating location.
- The control/safety system should initiate an ESD I with a trip signal to both ships prior to activation of the ERS and bunkering system disconnection (ESD II).
- In the event of the ships breaking away (exceeding operating envelope), the ERS must automatically operate and release the transfer system.
- The design of the ERS should comply with EN ISO 20519 paragraph 5.4.3 and SIGTTO Guidance on ESD Arrangements & Linked Ship/Shore systems for Liquefied Gas Carriers.

The ERS is to be designed as one of the following:

- Two ERC valves mechanically interlocked and operated simultaneously by a single actuator. This action is to enable the activation of the ERC.
- Two ERC valves to be operated independently of the ESD, by two interlocked actuators. Design arrangements are to be provided to prevent the opening of the ERC. When separated, the valves are to remain safely closed even in case of hydraulic or electric power failure. An electric, hydraulic or mechanical system is to be provided to prevent reopening of the valves before reassembly of the ERS after disconnection.
- Alternative designs that comply with the safety principles of EN 1474-1/ISO 16904 will be considered provided they carry appropriate Certification/Classification approvals.

The ERS should be designed to ensure that the ERS is active only during LNG transfer and testing. A manually operated hydraulic valve is to be installed on the hydraulic supply line to secure it when the arm is not connected to the receiving ship's manifold.

Fire Detection

Automatic fire detection systems consist of mechanical, electrical or electronic devices that detect environmental changes created by fire extraneous to the LNG bunkering operation or via leakage and inadvertent combustion of the leaked methane vapour. Fire detectors operate on one of three principles, sensitivity to heat, reaction to smoke or gaseous products of combustion, or sensitivity to flame radiation.

- Heat Sensing Fire Detectors fall into two general categories, fixed temperature devices and rate-of-rise devices. Some devices combine both principles (rate-compensated detectors). Generally, heat detectors are best suited for fire detection in confined spaces subject to rapid and high heat generation, directly over hazards where hot flaming fires are expected, or where speed of detection is not the prime consideration.
- Smoke Sensing Fire Detectors are designed to sense smoke produced by combustion and operate on various principles, including ionisation of smoke particles, photo-electric light obscuration or light scattering, electrical resistance changes in an air chamber and optical scanning of a cloud chamber.

- Flame Sensing Fire Detectors are optical detection devices that respond to optical radiant energy emitted by fire. Flame detectors responsive to infra-red or ultraviolet radiation are available, with the ultraviolet sensitive detectors generally employed.

Fire Fighting

Firewater spray systems should be provided for LNG bunkering operations in line with IGC and IGF code requirements for the following purposes:

- Fire-fighting and in combination with foam (AFFF) can provide pool fire suppression
- Cooling effect against thermal radiation from an adjacent fire
- Speedy dilution of LNG spills thus improving cryogenic protection
- Mitigating any explosion effects

The firewater spray system should provide coverage for boundaries of the superstructures, pump rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face an LNG fuel tank on open decks unless the tank is located 10 metres or more from the boundaries. The spray system should also provide cooling coverage to all exposed parts of the LNG tank if this is located on open deck.

The system should be designed to cover all areas as specified above with an application rate of 10 l/min/m2 for the largest horizontal projected surfaces and 4 l/min/m2 for vertical surfaces. Stop valves should be fitted in the spray water application main supply line(s), at intervals not exceeding 40 metres, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected.

The spray system may be part of the fire main system provided that the required fire pump(s) capacity and working pressure are sufficient for the operation of both the required numbers of hydrants and hoses and the water spray system simultaneously. The capacity of the water spray pump(s) should be sufficient to deliver the required amount of water to the hydraulically most demanding area that requires protection. Remote start of pump(s) and remote operation of any normally closed valves to the system should be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

Furthermore, a permanently installed dry chemical powder fire-extinguishing system should be installed in the bunker station on board the receiving ship to cover all possible leak points. The capacity shall be at least 3.5 kg/s for a minimum of 45 s. The system shall be arranged for easy manual release from a safe location outside the protected area. In addition to any other portable fire extinguishers that may be required by SOLAS, IGC and IGF codes (upon enforcement of IGF code), one portable dry powder extinguisher of at least 5 kg capacity shall be located near the bunkering station.

2.5. Equipment certification

As recommended by IACS Rec.142, Equipment Certificates must be sighted and accepted prior to performing LNG bunkering at the Port.

Equipment Certificates should be found for, as a minimum, the components from LNG bunkering trucks, barges, vessels, storages and Receiving Vessel detailed in [B2 Annex 1.1.].

3. LNG Bunkering Procedures

3.1. Description of LNG bunkering general process

As described in this chapter, from the storage facility or terminal there are three basic methods to deliver the LNG to the end user:

- Truck to Ship TTS, the requirements also apply to Multiple Trucks to Ship MTTS.
- Ship to Ship STS
- Pipeline to Ship PTS

An outline of LNG bunkering is presented below. This procedure is primarily applicable to STS bunkering but can be adapted and simplified for other bunkering methods.

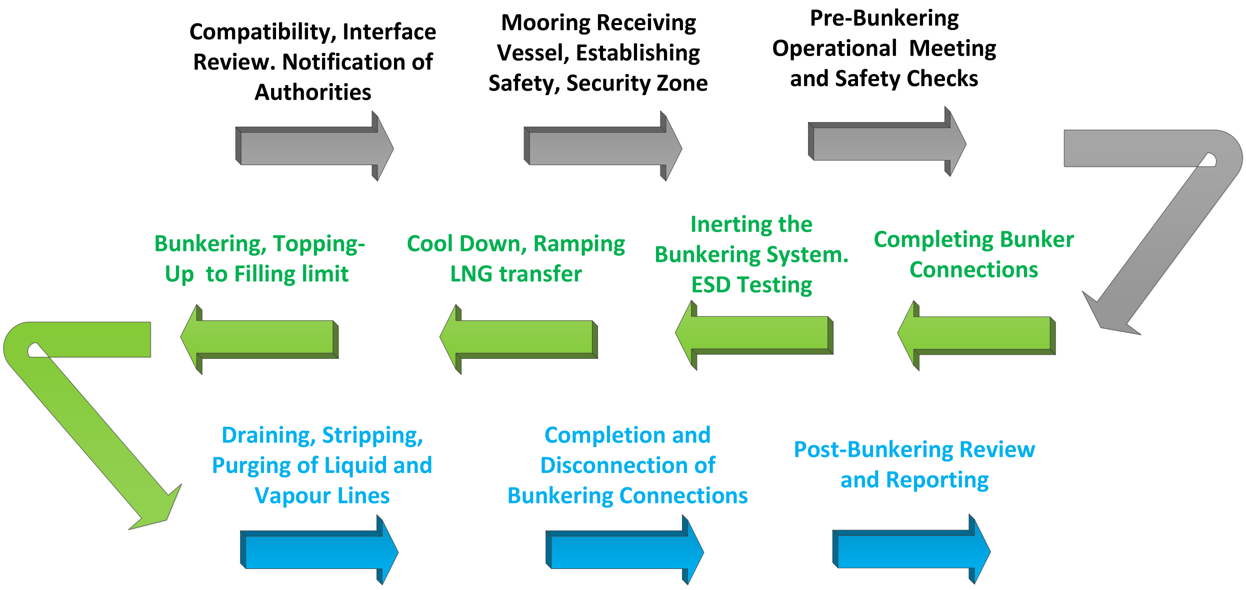


Figure 3.1 Schematics of general LNG bunkering process

In addition to referring the LNG Bunkering Procedures detailed in the EMSA Guidance on LNG Bunkering dated 31st January 2018, the following is recommended for each procedure stage:

3.1.1. Compatibility, Interface Review and Notification of Authorities

The LNG bunkering asset (i.e. truck, ship, piping from fixed LNG storage) will have defined the type, size, category of receiving ships that it can effectively and safely transfer LNG into.

A compatibility review should be carried out prior to agreeing to carry out a planned bunkering operation. This review will take into account different physical interfaces such as piping/hose manifold connections and software such as bunker control software including safety systems between the bunkering asset and the receiving vessel. Some physical information to be verified will include: arrival draught, freeboard, height of bunker station above waterline, including height difference between manifolds during discharge. Height information is critical as it will affect the ability of the bunker asset to carry out the bunkering operation especially if a marine loading arm will be used. The use of flexible hoses allows a greater range of manifold height differences to be accommodated depending on the design of the supporting structure such as a crane.

After agreeing on the compatibility and interfaces between BFO and the RSO, the parties should notify the local Port Authorities. Giving the Port Authority advanced notice will allow dedicated personnel to be made available as necessary i.e. from conducting license holder audits to providing assistance such as identification of local emergency services to be on standby in case of emergencies.

3.1.2. Mooring the Receiving Vessel and Establishing the Control Zones

The mooring arrangement should securely hold the receiving vessel to a pier such that LNG bunkering system components i.e. couplings, hoses and their supporting arrangement, loading arms will not be adversely affected by relative motion caused by weather conditions and changes in draft during the bunkering operation. Reference to requirements related to the mooring arrangements and its impact on LNG bunkering operation and equipment can be found in ISO28640, ISO20519, EN1474-2, EN1474-3, EN16904, and best practice guidelines from OCIMF publications, namely within OCIMF Guidelines for the Safe Transfer of Liquefied Gas in an Offshore Environment, and OCIMF Effective Mooring 3rd Edition 2010 publication.

There are four control zones -detailed in [C 5.4]- that should be established and maintained prior to the commencement of the LNG bunkering.

Hazardous (Area) Zone:

All electrical and mechanical equipment within the hazardous zone must be suitably rated (i.e. safe type) such that ignition risks are adequately minimised and controlled. Access to the hazardous areas should be limited to bunkering personnel with intrinsically safe type clothing, PPE and tools.

Safety Zone:

In any case, the safety zone is predetermined and should be enforced prior to connection of the LNG transfer system. This is achieved by:

Temporarily removing all sources of ignition within the safety zone for the entire duration of the bunkering operations.
Restricting access to designated bunkering personnel only.
Restricting dropped object hazards by temporarily suspending crane operations, forklifts and stackers.
Temporarily removing collision hazards by restricting vehicular access, port mobile equipment and passing vessels.

Reviewing the availability of the hazard prevention measures and mitigation such as gas detection, fire detection, fire-fighting systems, etc.

Security Zone

A reasonable buffer distance (i.e. a few meters) should be established between the safety zone and the adjacent Port location to ensure the safety of the general public including a safe working environment for bunkering personnel. Procedures for effecting the security zone require the following:

Area marking using reflective paint, cones and other highly visible materials that are effective under all envisaged bunkering conditions - such as during night and inclement weather;
Monitoring personnel, in the event SIMOPs are planned such as embarkation/ disembarkation of passengers such that the general public can be effectively directed to stay away from the safety zone.
Establishing temporary speed limits for moving vehicles in traffic lanes passing close to security zone.

Marine Zone

Marine Zones are port specific and enforcement should be done by Port Authority either by physical signals or a communication procedure in order to avoid the navigation of other ships close to the bunkering operation.

3.1.3. Pre-bunkering operational meeting and safety checks

A pre-operation review meeting between all parties i.e. the bunker supplier person in charge (PIC), the receiving vessel's PIC and the terminal representative when required should occur to agree on the details of the bunkering operation. This means the procedures and operational parameters with respect to the manifold connection, dry coupling, emergency release, purging, flow-rates for each stage of bunkering (cool down, ramp-up, full-flow, topping up to filling limit) including any limitations will be formally agreed between the parties.

In case of planned Simultaneous Operations (SIMOPs) within the control zone (safety zone, security zone), personnel responsible for carrying out parallel activities should be given clear instructions including safety pre-cautions and emergency response actions and a common communication channel fixed in order to receive emergency instructions.

Finally, an inventory and functional check of PPE, cryogenic protection, monitoring components should be carried out to confirm their availability for the bunkering operation.

Checklists specific to the planned bunkering operation and SIMOPs should be completed and retained.

3.1.4. Completing the bunkering connection

Depending on the type of bunkering asset (i.e. truck, vessel, piping from fixed storage tank), there can be multiple pipe/hose connections for liquid, vapour and inert gas and interfaces for bunkering control including the emergency shutdown system.

Hose handling equipment (e.g. cranes, supporting infrastructure) or fixed pipe loading arms should be set in position to facilitate the connections and a proper disconnection in case of ERS activation. The manifolds from either end should be earthed and an insulation flange should be fitted to the receiving ship to prevent electrostatic build up. For the bunkering control and Emergency Shut Down (ESD) arrangements, there can be different types of interfaces and connections – beginning with the older pneumatic link system to more modern electric-based links (e.g. SIGTTO, Miyaki, Pyle National, etc.) and fibre optic.

3.1.5. Inerting the Connected LNG Bunker System and ESD Testing

Prior to connection, the bunker piping of the receiving vessel should be maintained in an inerted condition. This is critical as it is essential to prevent oxygen from entering and accumulating in the LNG bunkering system. Nitrogen sourced from pressurised bottles is flushed through the pipes and hoses to ensure that all parts of the system are sufficiently inerted maintaining the oxygen level to less than 4% by volume. Once all manifold/piping or hoses have been purged using nitrogen and the connection of the bunkering equipment is completed, the connections will then be pressurised and tested for leakages.

Also, both parties should periodically confirm the functionality of their emergency shutdown systems prior to executing the bunkering operations. This will involve the following tests:

- Mechanical, hydraulic, electrical release mechanism of the emergency release system to be confirmed operational and ready.
- Visual inspection and testing of the dry connect, disconnect couplings.
- ESD I function including safety logic should be tested and proven operational.
- The test completion and results should be documented and made available for audit of the port authority.
- Any defects, anomalous results from the tests should be effectively reported to the PIC for consideration prior to proceeding with the LNG bunkering.

3.1.6. Cooling down and Ramping LNG Bunkering Flow

The receiving vessel may pre-cool some of the LNG bunker piping and the LNG tank, reducing the vapour pressure through re-circulation and the use of the tank spray arrangement prior to arrival. Subsequent to the connection and completion of purging, LNG vapour will be slowly introduced to the bunker piping until thermal equilibrium is reached. This means the LNG piping, the manifold and the hoses reaching an average temperature of -130 ºC i.e. temperature gauges at the manifold. Note that cooldown should be carried out iteratively, slowly introducing vapour into the LNG pipe. Repeated abrupt cooldown of the LNG pipes, hoses and valves will generate excessive thermal stresses, resulting in fatigue damage and cracks. Once the entire connected LNG transfer system reaches a temperature of -130 ºC or below, LNG transfer can be ramped up towards the desired flow capacity. Initially the receiving LNG tank will be filled using the top spray connection, to reduce the remaining vapour in the tank and achieve further cooling effect. When the receiving tank temperature approaches -150 ºC, the LNG transfer can be raised to the agreed rate.

During the entire cooldown, ramp-up of LNG transfer rate requires special precautions to be taken to avoid the release of gas vapours to the atmosphere. Vapour management techniques will include but are not limited to:

- use of a dedicated vapour line to send back the BOG to bunkering Facility.
- use of a dedicated vapour receiving tank for pre bunkering and post bunkering purging operations.
- Boil-off gas management such as purposely built gas combustion units or other dual fuel machinery to use the vapour.

3.1.7. Slowing down LNG transfer, Topping-up to Loading Limit (Filling Limit).

Each receiving tank has a defined loading limit and filling limit that shall not be exceeded during bunkering. The IGF code requires the filling limit to be no more than 98%, with the corresponding loading limit calculated based on the ratio of the relative density of LNG at the reference temperature (i.e. the relief conditions of the tank) and its relative density during loading. The loading limit is not a fixed amount, rather it is a curve describing the ratio of the LNG density at relief condition versus the density of fresh LNG during bunkering. Meaning the loading limit accounts for the expansion effect (increase in volume) of the LNG should the tank be exposed to fire, minimizing the possibility of LNG being vented through the relief valve.

A tank accidentally exceeding its loading limit curve during LNG bunkering shall be reduced back to the loading limit to avoid the potential of two-phase flow being ejected from the tank vent mast in the case of fire. After each bunkering, the final loaded condition of the tank should be reported alongside a copy of the loading curve and made available to the port authority.

3.1.8. Draining, Stripping and Purging of LNG and Vapour Transfer Lines

On completion of the bunkering operation all LNG transfer piping and hoses should be drained and stripped to remove pockets of LNG. Remaining LNG in the piping can result in pressure build up, as the ambient environment warms up the LNG resulting in volumetric expansion. After stripping LNG from the piping and the hoses, purging using nitrogen will be performed to displace the vapour content in the piping to less than 3%. Purging is more effective with the provision of a dedicated receiving tank and/or gas combustion unit.

3.1.9. Completion, Disconnection and Stowage of LNG Bunkering Connections

Disconnection begins with bunkering connections for liquid, vapour and inert gas piping and hoses. The dry disconnect coupling connecting the piping or hoses should be activated then followed by the interfaces for bunkering control including the emergency shutdown system. Subsequently all hose handling equipment (e.g. cranes, supporting infrastructure) or fixed loading arms should be disengaged and set clear of the receiving ship.

The dry connect/disconnect coupling, emergency release coupling and ESD interfaces should be handled safely avoiding mechanical damage from accidental drops and making sure they are stowed to minimize corrosion.

3.1.10. Post-Bunkering Review and Reporting

In addition to agreeing on the quality and quantity of LNG bunkered, checklists in line with IAPH LNG (see chapter 3.4) bunkering should be completed and retained for records. All bunkering incidents such as non-compliance with protocols, miscommunication and failure of any components should be recorded and reported to the Port Authority.

3.2. Vapour Management

Bunkering operations should ensure that no LNG vapours (methane) will emit to the environment as a result of normal bunker transfer. Given the harmful effects of methane as a greenhouse gas and the general safety issues concerning inadvertent ignition, venting should be considered as an emergency action only. A vapour management system should be fully integrated with the bunkering Operating Procedures to ensure that no vapour pressure throughout the bunkering operation will exceed the relief valves maximum operating pressure resulting in over pressurization and relief.

LNG boil-off gas (BOG) generation is a natural phenomenon that is expected during storage, transportation, and transfer of LNG irrespective of the advances in containment and insulation technology. When LNG is stored at a particular pressure, the tank contents must be maintained below or equal to the corresponding saturated temperature to allow methane/natural gas to remain in a liquid state. The entire LNG supply chain has been developed around management of supply and demand, containment, and insulation technologies to limit boil off gas (BOG) generation. It must be emphasized that no matter what type of tanks (pressure vessels, prismatic, etc.) are used or how good a design incorporating the latest insulation technology is, heat transfer will occur as a result of the vast temperature difference between the LNG and the surrounding environment.

Understanding the specific mechanics of BOG generation during the different phases of a LNG supply and bunkering operation will pave the way for safely handling the BOG without resorting to methane release. It is imperative that BOG is managed safely and efficiently as marine rules and regulations explicitly require that no methane vapours are released as part of normal operation. EMSA guidance for LNG bunkering indicates that: "*Venting to the atmosphere, either resulting from automated or manual action, through PRV actuation, or through any other possible outlet from the LNG storage or bunkering system, should be only possible in case of emergency, for safety reasons.*"

The most relevant factors that will affect the amount of BOG generation in a typical bunkering operation are as follows:

Purging and cool down of the transfer system,

Difference in the conditions prevailing between the bunker tanker storage tanks and the receiving ship storage tanks. It should be emphasized that a bunkering operation results in the interaction between two initially separated containment systems, resulting in changes in pressure and temperature conditions on both tanks,

Transfer rates (ramp up, full flow, ramp down/topping up),

Heat leakage rate.

There are typically three sources of BOG during bunkering operation. The following paragraphs describes each one and means of BOG mitigation, including removal and utilisation:

3.2.1. BOG within receiving LNG storage tank

Prior to a bunkering operation, the LNG storage tank(s) of a RSO will be nearly empty of LNG save for a minimal amount. Natural gas vapours will occupy most of the tank volume and as a result of continuous heat ingress to the LNG tank; it will be kept at a higher pressure compared to the LNG bunker supply.

The BOG management in place should be designed to meet the most onerous condition (i.e. maximum BOG in existence and generated) at any point during the bunkering operation. A technique employed in gas fuelled ships including LBV/LBB fitted with gas fuelled machinery is by simply removing BOG from the tank vapour space.

Removing the BOG not only reduces pressure in the tank but also helps eradicate some of the heat stored. The BOG is supplied to gas fuelled machineries that are in use during the bunkering operation. In cases where gas fuelled machinery are not functioning during bunkering operation, a load in the form of a dual fuel boiler operating in “dump steam” mode can also be used.

A feature of the current gas fuel systems on-board some RVs involves the use of a pressure vessel (IGC code independent type C tanks) for LNG storage. These tanks are typically designed to safely contain LNG at pressures much higher than the intended tank working pressure. While pressurized storage cannot reduce BOG generation, from a BOG management perspective the tank can be designed to hold BOG at elevated pressures for extended periods discounting the potential for inadvertent venting. In addition to the ability to hold BOG at elevated pressures, type C tanks are also fitted with a top spray arrangement. Spraying LNG within the vapour space will result in the collapse of the BOG, which in turn lowers the tank pressure allowing for bunkering without the use of a vapour return line. The top spraying arrangement, whilst an effective BOG management technique will put a limit on the bunkering flow rates that a receiving LNG tank and transfer system can accommodate.

3.2.2. BOG generated during purging and bunker system cool down process

Classification Society Rules require LNG bunker pipes which are not in use to be purged and inerted with nitrogen. As a result of being initially inerted, LNG bunker piping will be considerably warmer than the LNG bunker and BOG will be generated during the nitrogen purging and piping cool down process.

As part of the cool down process, it is important to emphasize that the difference between the LNG bunker temperature and the transfer piping system temperature is the ‘motive force’ that propels heat transfer resulting in BOG generation. The larger the temperature difference, the more heat transfer which in turn produces more BOG that needs to be addressed by the system.

BOG will occur in the transfer piping system when the system at ambient temperature is opened to allow LNG flow. As the LNG moves along the piping, heat is transferred from the stainless-steel pipes and piping components to the LNG. This will boil off a quantity of the LNG until the pipeline and valves reach the same temperature as the LNG bunker.

A practical consideration in this respect is to ensure that transfer system components with mass (e.g. isolation valves) approximate the temperature of the LNG bunker before introducing the full bunkering flow rates. The more material a piping component contains (e.g. ball valves used for isolation), the longer the cool down period should be as more boil-off gas will be produced if full bunkering capacity is introduced. The amount of BOG generated as a result of piping components having a thermal gradient is relatively minimal and should be safely addressed by the tank spraying arrangement and consumption of gas fuelled machinery as discussed in (a) above.

3.2.3. BOG generated as a result of the transfer/pumping process

In addition to the BOG occurring as a result of heat leaking through the equipment and piping, motions affecting the storage tanks as a result of transportation and pumping/pressurising the LNG during the transfer operation will all lead to BOG generation. Although limited when compared to other sources, BOG as a result of agitation (mechanical energy being imparted to the LNG) during the pumping process is unavoidable. The BOG management and design provision identified earlier on are well adept in dealing with the effect.

From a LNG bunker supplier perspective, it is worthwhile to emphasise that the amount of BOG that can be generated in the process is as a function of the heat being absorbed through the LNG storage and supply chain. While BOG management and design provisions discussed such as insulation, application of pressure vessel tanks, etc. are helpful, the most effective BOG mitigation can be best achieved through efficient operational planning. In practical terms this would mean that the bunker supplier should not hold LNG for prolonged periods of time, limit the amount of intermediaries in the LNG supply chain and account for the storage capacities of gas fuelled ships to be bunkered for a particular operational run. As bunker facilities are expected to grow in size allowing for economies of scale, a re-liquefaction plant may turn to be an attractive option, simplifying the BOG management of the LNG storage facility and the bunkering operation itself.

3.3. EMSA Guidance on LNG Bunkering: Schematics

The [EMSA Guidance on LNG Bunkering] describes the LNG Bunkering Procedures in detail for each of the main LNG transfer methods, including the bunkering workflow from cooldown to disconnection. It identifies actions in terms of bunkering valve positions (open/close) including diagrammatic illustrations. Generally, these procedures are considered adequate for safe LNG bunkering operations. We include copies of the main schematics for easy reference.

3.3.1. Truck-to-ship bunkering

Table 3.1 TTS LNG bunkering general characteristics. Source: EMSA Guide

Truck-to-Ship - TTS	
Short Description	LNG truck connected to the receiving ship on the quayside, using a flexible hose, assisted typically by a hose-handling manual cantilever crane.
Typical Volumes (V) [21]	V ≈ 50-100m3
Typical Bunker transfer rates (V) [21]	Q ≈ 40-60m3/h
Operational characteristics and possibilities	• Operational Flexibility, with bunkering possible in different locations within the same port, serving different ships in different conditions. • Operation highly dependent on the transfer capacity of the truck, typically small (see above). • Possible to deliver LNG very close to receiving ship, minimizing: – heat transfer through the bunkering hose – pressure drop along the bunkering line – trapped volume, • Limited Infrastructure requirements, with no necessary • Possibility to adjust delivered volumes (Nr. of trucks) to different client needs. • Possibility to adapt to different safety requirements. • Possibility to serve different LNG fuel users on point-to-point delivery • RO-RO/PAX ferries may be bunkered from a location in main car/cargo deck. Control for such operation to be
Limitations	• Limited capacity of trucks: approximately 40-80 m3 is likely to dictate multi-truck operation. • Significant impact on other operations involving passengers and/or cargo. • Limited movement on the quay-side, mostly influenced by the presence of the bunker truck(s). • Exposure to roadside eventual limitations (permitting, physical limitations, traffic related, etc.)

Type C tank to Type C tank bunkering:

Most LNG bunkering operations involve type C tanks as both supply and receiving tanks. Type C tanks provide distinct advantages for bunkering given their conformance with pressure vessel design principles resulting in higher operating and relief pressures (i.e. commonly set at 10 bar-g). This robust construction minimises the risk of over-pressurisation and inadvertent release of gas vapours during bunkering operations. Having said this the initial temperature and working pressure of the receiving tank should be managed by effective cool down operations to allow full flow of the LNG pumping capacity. Towards the end of the transfer operation i.e. topping up stage, close attention should be given on complying with the approved filling limit (e.g. 85%) of the type C tank.

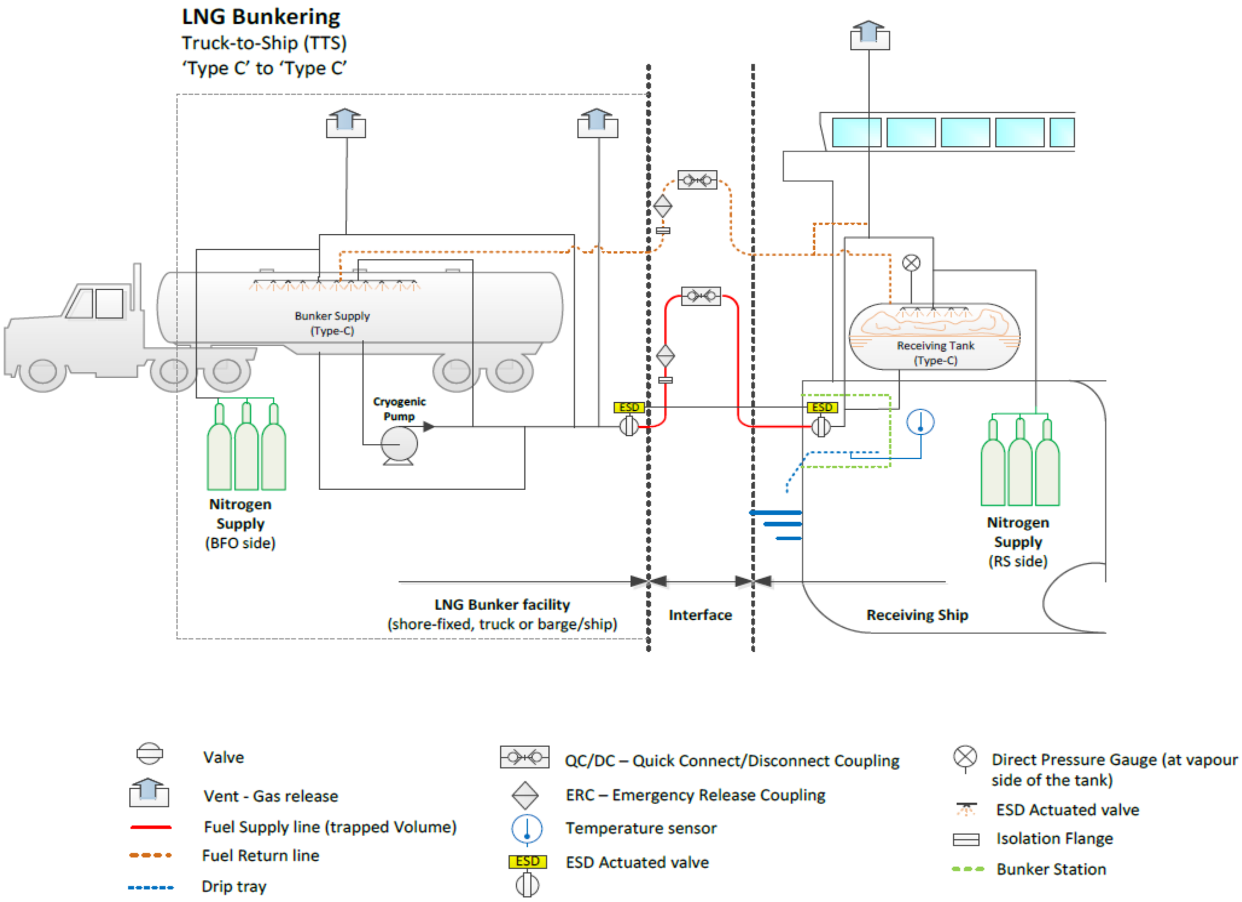


Figure 3.2 EMSA Guidance on LNG Bunkering: Schematic for Truck to Ship LNG Bunkering

3.3.2. Ship-to-ship bunkering

Table 3.2 STS LNG bunkering general characteristics. Source: EMSA Guide

Ship-to-Ship - STS	
Short Description	LNG is delivered to the receiving vessels by another ship, boat or barge, moored alongside on the opposite side to the quay. LNG delivery hose is handled by the bunker.
Typical Volumes (V) [21]	V ≈ 100-6500m3
Typical Bunker transfer rates (V) [21]	Q ≈ 500-1000m3/h
Operational characteristics	• Generally does not interfere with cargo/passenger handling operations. Simultaneous Operations (SIMOPS) concept is favoured. • Most favourable option for LNG bunkering, especially for ships with a short port turnaround time. • Larger delivery capacity and higher rates than TTS method. • Operational flexibility – bunkering can take place alongside, with receiving vessel moored, at anchor or at station
Limitations	• Initial investment costs involving design, procurement, construction and operation of an LNG fuelled vessel/barge. • Significant impact in life-cycle cost figures for the specific LNG bunker business. • Limited size for bunker vessel, conditioned by port limitations

Type C tank to Type C tank bunkering:

Considerations for this type of operation are similar to TTS supply.

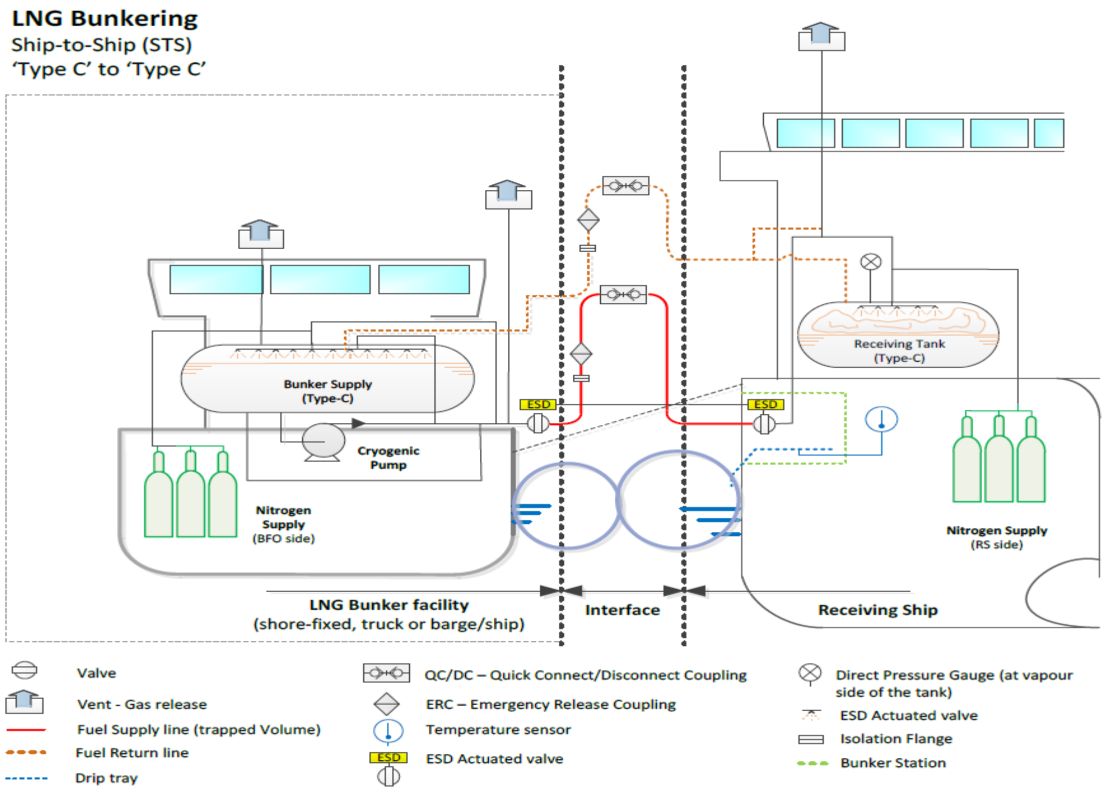


Figure 3.3 EMSA Guidance on LNG Bunkering: Schematic for Ship to Ship LNG Bunkering between Type C tanks

Atmospheric tank (i.e. membrane type) to Atmospheric tank (i.e. membrane type) bunkering:

Both supply and receiving membrane tanks will be provided with systems that actively manage the boil-off gas. Having said this both supply and receiving tanks will have very little tolerance for over-pressurisation (i.e. membrane tanks operate close to atmospheric pressure conditions) requiring close monitoring and anticipation of boil-off gas generation. Managing the boil-off gas can take one or a combination of the following methods:

Operation of gas consumers (dual fuel engines, gas boilers) in the receiving ship as a parasitic load.
Activation of boil-off gas compressor and pressure vessel for BOG accumulation (if available)
Incineration using a gas combustion unit.
Extraction and liquefaction using a gas re-liquefaction plant.

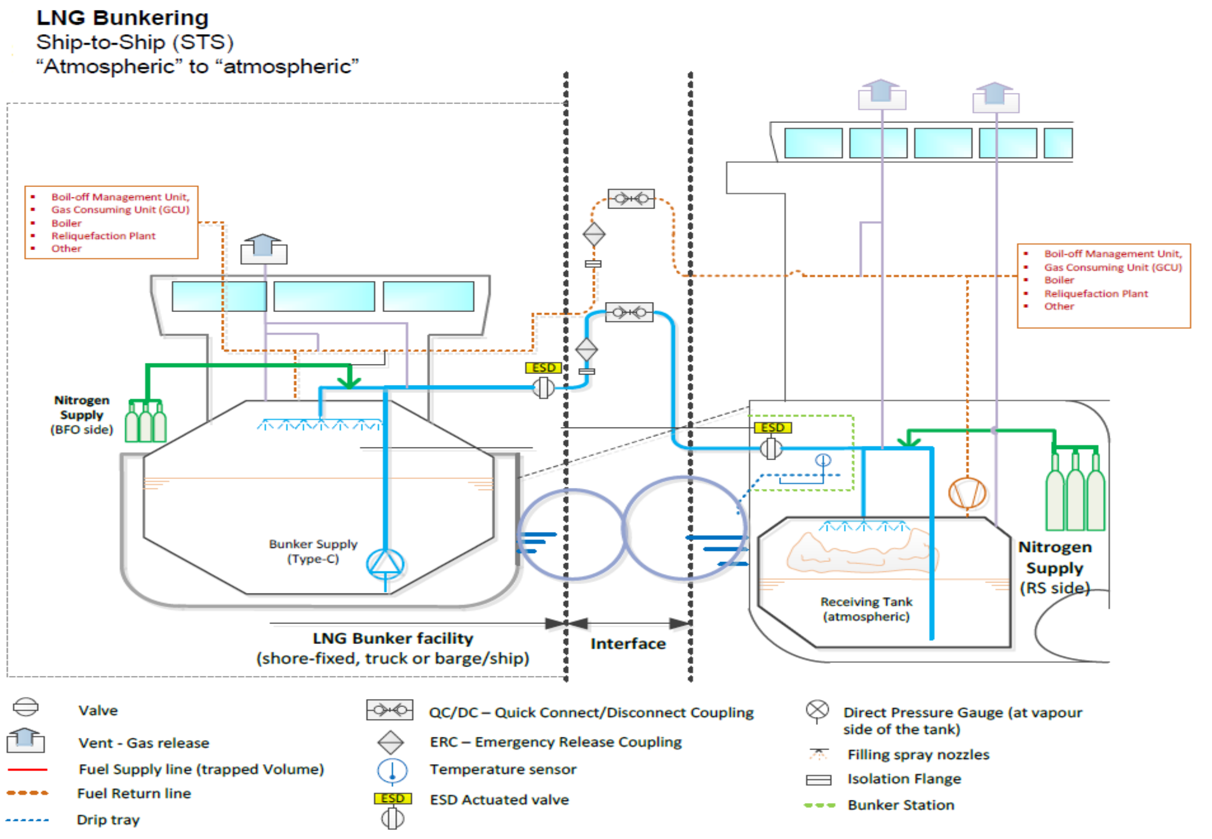


Figure 3.4 EMSA Guidance on LNG Bunkering: Schematic for Ship to Ship LNG Bunkering between atmospheric tanks

Type C tank to Membrane tank bunkering:

This bunkering arrangement could be seen happening between RVs and LBVs.

Bunkering operations involving membrane tank as a receiving tank require active boil-off gas management, before and during bunkering operations. Membrane tanks have a distinct requirement to remain at or very close to atmospheric pressure conditions. Given the large relative volume of membrane tanks (thousands of m³) they require the provision and operation of a boil-off gas management system during the different phases of the bunkering operation. Having a large vapour space encourages the generation of flash gas from the incoming LNG bunker. Managing the boil-off gas can take one or a combination of the following methods:

- Operation of gas consumers (dual fuel engines, gas boilers) in the receiving ship as a parasitic load.
- Sending the boil-off gas back to the type C tank vapour space.
- Activation of boil-off gas compressor and pressure vessel for BOG accumulation. (if available)
- Incineration using a gas combustion unit. (if available)
- Extraction and liquefaction using a gas re-liquefaction plant. (if available)

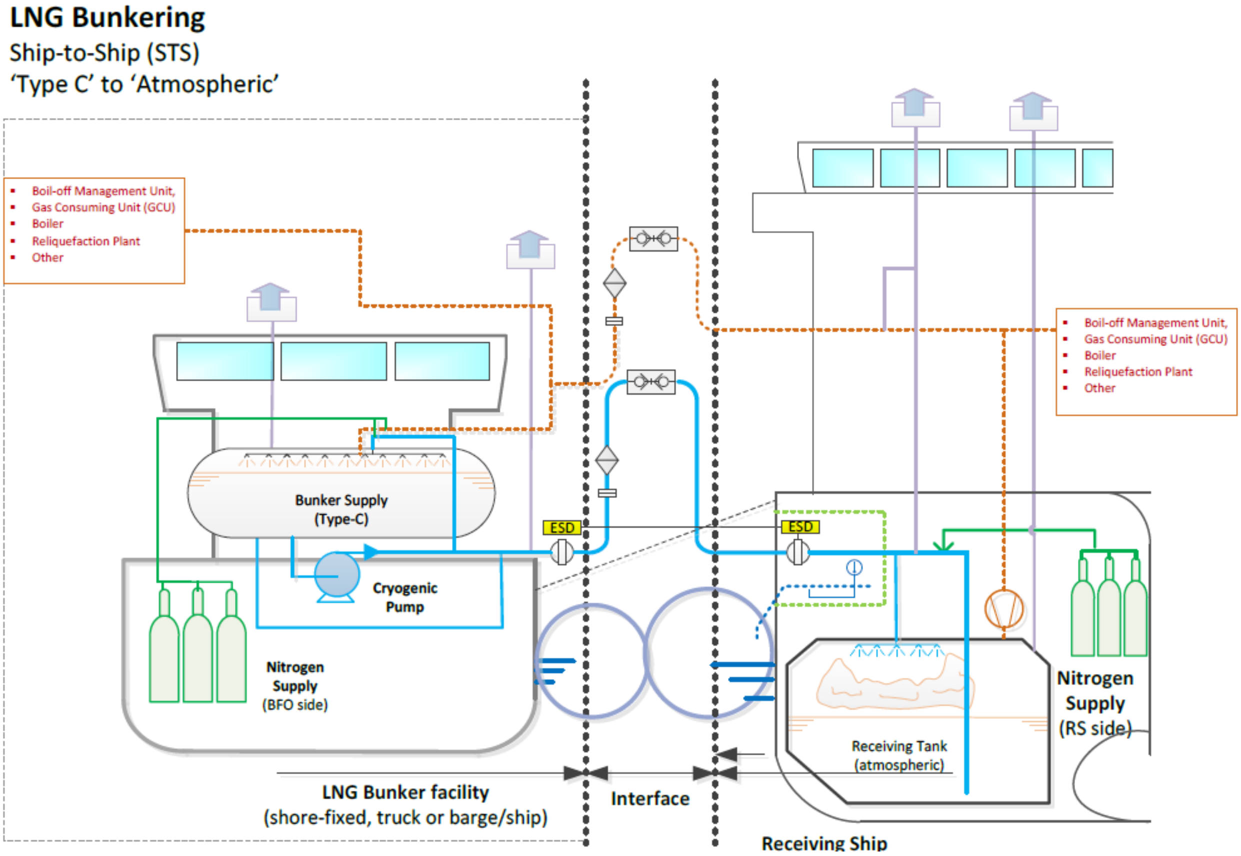


Figure 3.5 EMSA Guidance on LNG Bunkering: Schematic for Ship to Ship LNG Bunkering between type C tank and atmospheric tank

3.3.3. Pipeline-to-ship bunkering

Table 3.3 PTS LNG bunkering general characteristics. Source: EMSA Guide

Port-to-Ship - PTS	
Short Description	LNG is either bunkered directly from a small storage unit (LNG tank) of LNG fuel, small station, or from an import or export terminal.
Typical Volumes (V) [21]	V ≈ 500-20000m3
Typical Bunker transfer rates (V) [21]	Q ≈ 1000-2000m3/h
Operational characteristics	• Possibility to deliver larger LNG volumes, at higher rates. • Good option for ports with stable, long-term bunkering demand
Limitations	• From operational perspective it may be difficult to get the LNG fuelled receiving vessel to the Terminal. • Proximity of larger LNG terminal may not be easy to guarantee. • Calculation of available LNG for delivery, in small storage tanks, can be difficult unless pre-established contract exist

Type C tank to Type C tank bunkering:

Considerations for this type of operation are similar to TTS supply.

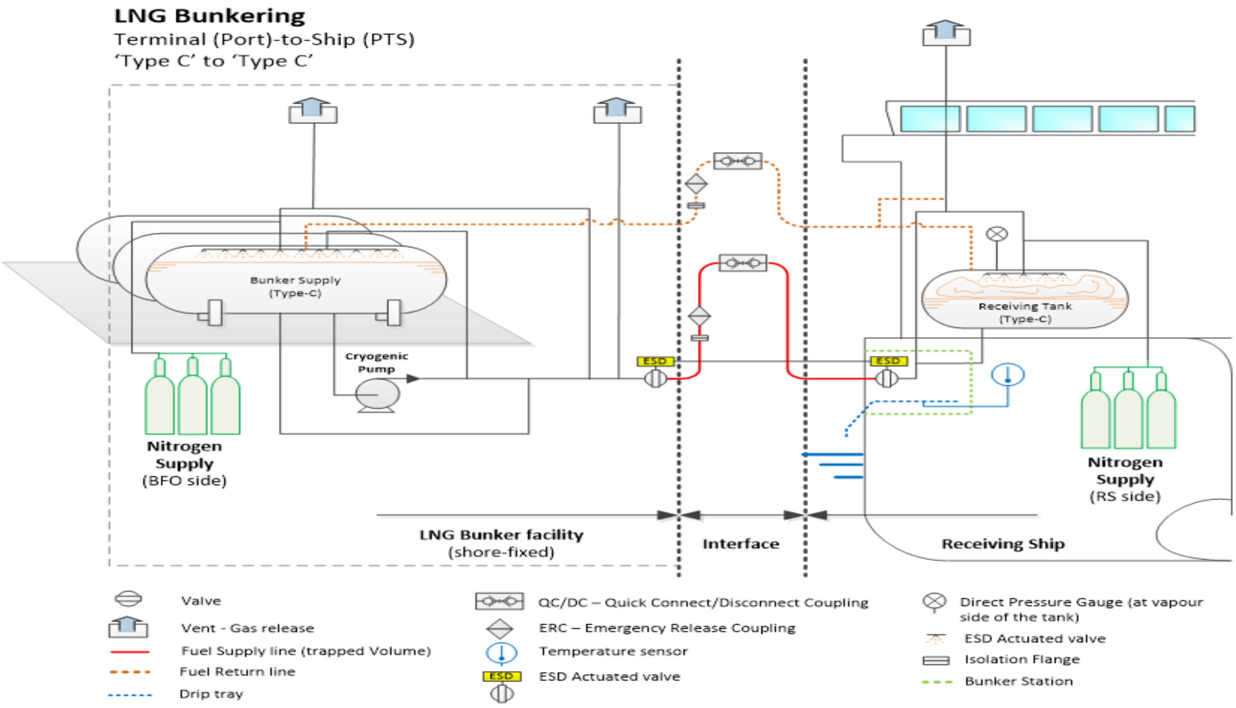


Figure 3.6 EMSA Guidance on LNG Bunkering: Schematic for Port to Ship LNG Bunkering between Type C and Type C tanks

Atmospheric tank (i.e. membrane type) to Atmospheric tank (i.e. membrane type) bunkering:

Both supply and receiving membrane tanks will be provided with systems that actively manage the boil-off gas. Having said this both supply and receiving tanks will have very little tolerance for over-pressurisation (i.e. membrane tanks operate close to atmospheric pressure conditions) requiring close monitoring and anticipation of boil-off gas generation. Managing the boil-off gas can take one or a combination of the following methods:

Operation of gas consumers (dual fuel engines, gas boilers) in the receiving ship as a parasitic load.
Activation of boil-off gas compressor and pressure vessel for BOG accumulation. (if available)
Incineration using a gas combustion unit.
Extraction and liquefaction using a gas re-liquefaction plant.

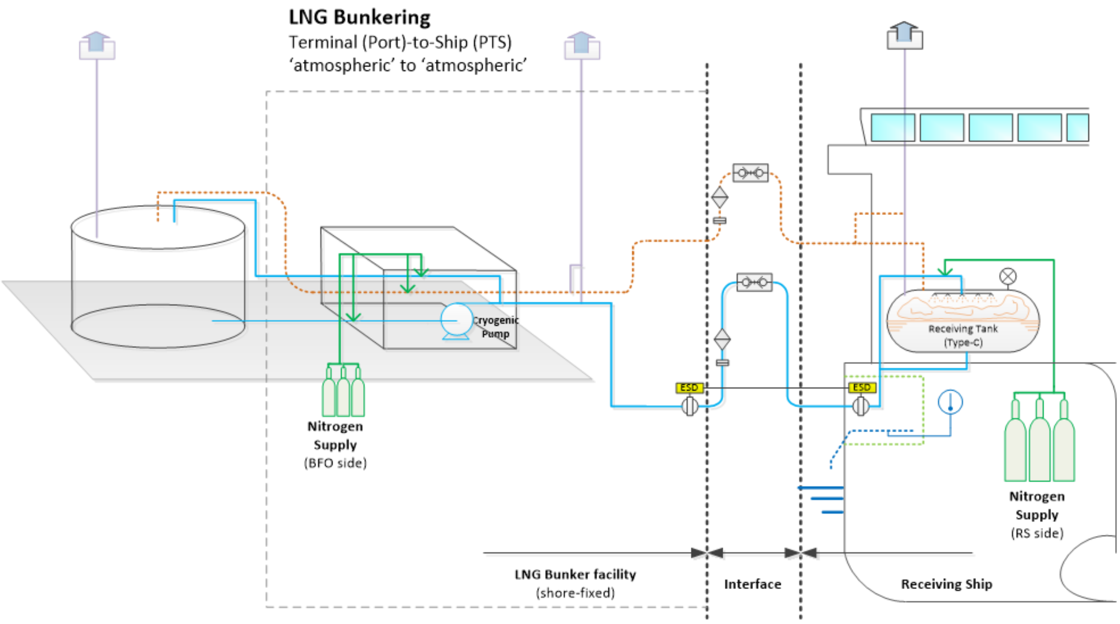


Figure 3.7 EMSA Guidance on LNG Bunkering: Schematic for Port to Ship LNG Bunkering from LNG atmospheric tanks

3.4. Operational checklists

The number of activities that are recommended to carry out when conducting LNG bunkering audits could become an unsurmountable large task prone to human error, unless we devise a way to conduct such audits with minimal risk of human mistake.

Conducting such an extensive amount of verification activities by all parties involved represents a significant challenge that it is typically managed and controlled by the adoption of agreed or approved Operational Checklists.

Operational checklists and conformance monitoring checklists are essential defences against LNG bunkering operation errors and LNG component, equipment, system faults and failures.

In a way a checklist is a special type of procedure, meaning checklists are the form into which long, formal written procedures are distilled, for the use of personnel in the field. For all aspects of the LNG bunkering operation, they are important tools for ensuring that the processes and relevant work are done correctly and safely. In addition to the design of the list itself, the checklist procedure includes the manner in which the checklist is to be executed (e.g., silent, challenge-and-response). Like any procedure, once a prototype checklist has been developed, it must be analysed and tested such that potential conflicts can be addressed, and the checklist must be thoroughly tested for feasibility and practicality.

Problems with checklist use and the crew failure to monitor the bunkering processes adequately have a long history in maritime bunkering accidents (e.g. fuel oil, lube oil, etc. Accidental releases). A typical bunkering operation requires a number of routine control inputs and actions which in turn requires frequent reading and verification of visual displays. Many of these actions are governed by formal procedures specifying the sequence and manner of execution, after which checklists are used to condense the intention of the procedures improving its readability and practicality. Throughout the bunkering, both crew on board RVs and LBVs and the PSP personnel are required to monitor functions, the state of connected systems and the status of the general environment specifically if there are concurrent parallel operations. Thus, the number of opportunities for error can be quite large especially on busy ports, complex, time constrained vessel loading/unloading operations.

Conducting such an extensive amount of verification activities by all parties involved represents a significant challenge that it is typically managed and controlled by the adoption of agreed and approved Operational Checklists.

In addition, the adoption of such approved checklists is aimed at minimising the risk by all parties involved of non-compliance with safety related requirements that are specific to the ships (RVs, LBVs) and the Port and Terminal involved in LNG bunkering operations.

Furthermore, checklists aid in the harmonization of requirements across the value chain, improving the quality of the LNG bunkering operations and reducing potential confusion caused by having to comply with different rules and regulations at different Ports.

In order to give an appreciation of the order of magnitude and importance of tasks related to LNG bunkering operations, the following list can guide Port Authorities on the detailed activities that are commonly audited in accordance with the approved LNG bunker management plan and that operational procedures and instructions are available and readily accessible.

1. Commensurate with the frequency and scale of the bunkering operation confirm that there is clear accountability and understanding of all tasks necessary by the BFO bunkering provider personnel, Terminal Operator and Receiving Vessel Crew.

2. Verify that all personnel involved in the LNG bunker operation have the appropriate training and understand the specific instructions relevant to the LNG bunkering component, equipment and procedures in use.

3. Verify that there are sufficient, adequately rested, competent personnel to safely execute all stages of the bunkering operation.
4. Confirm that there is adequate planning and preparation prior to commencement of bunkering.
5. Interrogate that both bunker provider personnel and Receiving Vessel's Crew understand and are able to use the emergency shutdown system. That there is a clear understanding of what failure, accident scenarios will warrant a manual emergency shutdown of the bunkering.
6. Establish that there is clear understanding of the time, pressure, temperature, flow rates necessary for purging, cooldown operations. The agreement should extend to the actual LNG transfer from ramp up – maximum flow rate profiles to topping off and monitoring the filling limit.
7. Confirm that LNG transfer system components and equipment are in good working condition including safety system components and equipment (e.g. gas detection, fire detection, fire-fighting) are available prior to bunkering operation. These will include evidence of functional tests, maintenance records and alarm, emergency shutdown tests.
8. That there is an effective means of communication between the receiving ship crew, bunkering facility personnel and the Terminal representative, and that this has been established and tested.
9. That there are clear instructions in setting and observing hazardous zones, safety zones and security zones (bunkering restricted areas) including the personnel that will execute the implementation and monitoring of zones and the Terminal personnel.
10. Confirm that all portable electronic equipment (e.g. radios, gas detectors, etc) are rated in line with the hazardous area classification.
11. Verify that the method of electrical insulation, ESD link and dry break couplings have been agreed by both receiving ship and bunker provider.
12. Monitor that any planned simultaneous operations (SIMOPS) adhere to the procedures and limitations set out in the LNG bunkering management plan. Ensure the Terminal representative is aware of the control zones, the specific SIMOPS to be performed and the emergency procedures of all parties involved.
13. Confirm that all safety equipment required for all parties involved including fire-fighting are prepared and readily available for immediate use.
14. Verify that the instructions for closing windows, doors, portholes and ventilation and HVAC inlets are executed on the Receiving Vessel, bunker facility and any Port infrastructure covered by the safety zone analysis as per LNG bunker management plan.
15. Verify that designated bunkering personnel involved in the connection and disconnection of the bunker hoses using dry connect/disconnect coupling have appropriate protective clothing and equipment.
16. Confirm that spill protection provisions (drip and spill trays) and equipment (water sprays) are prepared and made available for use.
17. The right dry connect/disconnect coupling, emergency release coupling, flexible hoses and their supporting arrangements are in good working order without any visible damage.
18. All instrumentation (pressure, temperature, level) relevant to the proper functioning and safety of the LNG bunkering operation should be confirmed to be operational. In addition, different alarms including those used for ESD initiation should be clear to all bunkering personnel.

19. Confirm that pressurised heat exchangers such as pressure build-up units are leakage free and in working order prior to bunkering.

20. Verify that rotating equipment used in bunkering and vapour management (i.e. centrifugal pumps, compressors) are in good working order.

21. Confirm that the purging and nitrogen systems are available and in good working order.

22. Confirm that vapour management including the use of reliquefaction plants are operational and capable of handling the maximum amount of boil off gas.

23. Verify that all LNG transfer piping, vapour return piping, flexible hoses, their connections such as manifold flanges, dry connect/disconnect couplings, emergency release couplings are free from leakages and well secured.

24. Verify that both Receiving Vessel and bunker provider personnel have clear understanding on the flow rates, volume of the LNG being transferred including the normal operating windows i.e. temperatures, pressures expected during the bunkering operation.

25. Confirm that LNG bunkering personnel can execute the correct receiving tank topping off protocols, respecting the filling limits. Also, that effective LNG stripping and gas purging are conducted prior to initiating disconnection.

26. Verify that the disconnection of dry connect/disconnect couplings does not inadvertently release gas vapours and that safe work instructions are followed for stowage of flexible hoses, coupling, ERC and their supporting mechanism.

27. Verify that the contents of the LNG bunker delivery note conform to the actual LNG quantity and conditions.

28. Complete incident reports and human factors reporting templates as and when necessary.

3.4.1. International Association of Ports and Harbours (IAPH) Checklists

LNG Bunkering Checklists are developed and supplied by the IAPH (International Association of Ports and Harbours), WPCI (World Ports Climate Initiative) and can be accessed on the following link: http://www.lngbunkering.org/lng/bunker-checklists/

In addition to the LR created Human Factors (Error) Recording Template shown on Table 3.5, we also recommend adopting the IAPH WPCI LNG Bunker Audit tool which can be also found on the same link referred to above~~.~~ They represent an online audit bunkering tool and the results of the audit including any defects, operational incidents, failures and accidents are planned to be centrally collected into a database specific for LNG bunkering; the more data populated in this database should enable better risk understanding and analysis of LNG bunkering operations globally.

We recommend the use of these checklists because we believe that the multi-faceted IAPH LNG bunkering checklists represent the experience on practical bunkering operations, instances errors, faults and failures and their corrections. Building on the experience from decades of fuel oil bunkering but also the distinct technological and operational nuances of LNG bunkering operations.

The checklists are structured as shown on Table 3.4.

The checklists include SIMOPS checklists when appropriate, as well as detailed guidance explaining how exactly to use them for completeness and common understanding for all parties involved. We recommend their adoption for all phases on Bunkering as proof of compliance with safe LNG Bunkering Procedures and SIMOPs, for STS, TTS and PTS transfer methods.

The checklist for STS distinguishes between LNG bunkering operations performed:

- At Terminals that are co-responsible for the safe conduct of the LNG bunkering operation, for which the IAPH LNG Bunker Checklist - Ship To Ship - Version 3.7a – June 2019 would apply. At these Terminals, the responsibility to secure compliance with the requirements set by the PA for a safe transfer of LNG reside in the BFO, the RSO and the Terminal Operator (TO).
- Those performed at Terminals where the responsibility for the safe conduct of LNG bunkering operations resides on the BFO and RSO. The IAPH Bunker Checklist – Ship To Ship – Version 3.7b – June 2019 would apply.

Table 3.4 IAPH WPCI LNG Bunker Checklist for TTS, STS and PTS LNG bunkering operations. Source: IAPH, 2017

IAPH LNG BUNKERING CHECKLISTS					
TTS **Truck to Ship**		**STS** **Ship to Ship**		**PTS** **Bunker Station to Ship**	
Part A	Planning Stage Checklist and Registration of Involved Representatives	**Part A**	Planning State Checklist and Registration of Involved Representatives	**Part A**	Planning State Checklist and Registration of Involved Representatives
	--	**Part B**	Planned Simultaneous Activities	**Part B**	Planned Simultaneous Activities
Part B	Pre-Transfer Checklist	**Part C**	Pre-Transfer Checklist	**Part C**	Pre-Transfer Checklist
Part C	LNG Transfer Data Checklist Agreed starting temperatures and pressures Agreed bunker operations Agreed maximum and minimum DECLARATION	**Part D**	LNG Transfer Data and Simultaneous Operations Checklist Agreed starting temperatures and pressures Agreed bunker operations Agreed maximums and minimums Agreed simultaneous LNG bunker / Oil bunker operations Agreed simultaneous LNG bunker / Cargo operation Restrictions in LNG bunker/cargo operations DECLARATION	**Part D**	LNG Transfer Data Checklist Agreed starting temperatures and pressures Agreed bunker operations Agreed maximums and minimums Agreed simultaneous LNG bunker / Oil bunker operations Agreed simultaneous LNG bunker / Cargo operation Restrictions in LNG bunker/cargo operations DECLARATION
Part D	After LNG Transfer Checklist DECLARATION	**Part E**	After LNG Transfer Checklist DECLARATION	**Part E**	After LNG Transfer Checklist DECLARATION

IAPH LNG Ready Terminal Guidance and Checklists for Port Authorities:

The new IAPH LNG Ready Terminal guide has created a Port Authority Checklist, to aid PA to determine a terminal's preparedness level for RVs bunkering LNG at their premises.

The checklists allow PA to examine:

- Terminal Organisation
- Terminal's General Awareness
- Terminal's Incidence Response preparedness, and
- Terminal's personnel awareness and training with regards to the LNG bunkering operations within the Terminal.

In examining Terminal's adherence with the four areas above, the PA can ensure that the risks inherent with performing LNG bunkering operations within Terminals are better managed and likelihood of incidents and accidents mitigated.

A copy of the IAPH ILRT-LNG-Port Authority Checklist-Document version 1.0 could be downloaded from the following link https://sustainableworldports.org/clean-marine-fuels/terminal-readiness/ by filling up a request for information, together with the IAPH ILRT-LNG-Explanatory document-Document version 1.0.

3.4.2. Human Factors (Error) Reporting Template

When it comes to auditing human related errors, we recommend the use of templates like the Table 3.5 shown below; this is a way to audit and report human related errors when bunkering LNG with the view of raising awareness and minimising them in practice, as well as ensure all human factors are proactively monitored and managed.

Table 3.5 LNG bunkering operation: Human Factors (Error) Reporting. Source: Lloyd's Register, 2018

LNG Bunkering Licence Holder	----------		Bunkering Phase	--------		
Receiving Ship Name			**Procedural Step**			
Type of Human Error	**Hardware component affected**	**Instrument, Software affected**	**Personnel involved**	**Consequence**	**Date and Time**	**Remedial Action(s)**
Perception Error						
1. Misheard						
2. Incorrect visual						
3. Late detection						
4. Repeated errors						
5. Misread, poor perception						
Memory, recall oriented error						
6. Forgot to monitor						
7. Omitted or late response						
8. Forgetting the information						
9. Forgot to store the information						
10. Mis-recall information or action						
11. Memory Failure						
12. Forgot to ask/share information						
Decision Making Error						
13. Mis-projection						
14. Poor decision and/or planning						
15. Late decision and/or planning						
16. No decision or no planning						
Quality of Action						
17. Information or data entry error						
18. Selection error						
19. Unclear information						
20. Incorrect information						
21. Non – performed action						
22. Timing error						
23. Information not transmitted						

3.5. Assessing and mitigating methane emissions

It is important to note the potential impact that methane (CH4) emissions can have on LNG as fuel greenhouse Gas (GHG) reduction potential.

CH4 emissions resulting either from methane releases throughout the LNG life cycle or from the logistic chain methane, is 25 times more powerful than CO2 as a greenhouse gas during a 100 year time span; for this reason, it is important to mitigate the release of this gas during LNG bunkering operations, so that the environmental benefits of adopting LNG as a marine fuel could be fully realised.

Methane release related to bunkering operations

The bulk of unwanted emissions from LNG bunkering originate during pre-bunkering preparation (i.e. inert gas freeing, introducing methane vapour and cool down) and post bunkering operations (i.e. methane gas freeing, then inerting).

Performing these processes effectively unfortunately results in some methane release because, on one hand, methane leaks could be expected when, for example, disconnecting dry couplings or through fugitive emissions generated by vibrating or malfunctioning safety valves; on the other hand, it is considered that smaller LNG bunkering assets (i.e. LNG trucks, smaller LNG bunkering barges) lack the infrastructure to safely collect, store and dispose of these inert gas – gas vapour mixtures.

General concern about methane emissions may be demonstrably lower than other marine-related issues today – particularly in comparison to the visible damage caused by something like a crude oil leak – but growing environmental awareness means that this is unlikely to remain the case for much longer. Incoming directives from the European Union, which include carbon pricing and emissions trading schemes for shipping are likely to force the issue further.

Being proactive in minimising methane emissions would require the collaboration and joint initiative of key stakeholders involved in order to secure a most effective outcome. Examples of potential initiatives that could be adopted are offered below for industry's consideration, subject to technical and economic viability:

- Develop fixed port infrastructure enabling the collection, storage and disposal of methane vapour and inert gas mixtures.
- Require LNG bunkering providers as part of the licencing process to pool together resources to facilitate safe collection and disposal of methane emissions.

EMSA Guidance on how to mitigate methane release during LNG bunkering operations

[EMSA] offers good guidance on methane release mitigations in their Section 3.3., focusing on identifying where there is potential for methane releases at the interface between the RSO and the BFO (Truck, LBV, Pipe/small scale bunkering station at Port or Terminal), and within the Port/Terminal end of the bunkering process.

Below figure is an extract from EMSA Guidance containing recommended best practices to be considered for different stakeholders involved in the bunkering operation at Port.

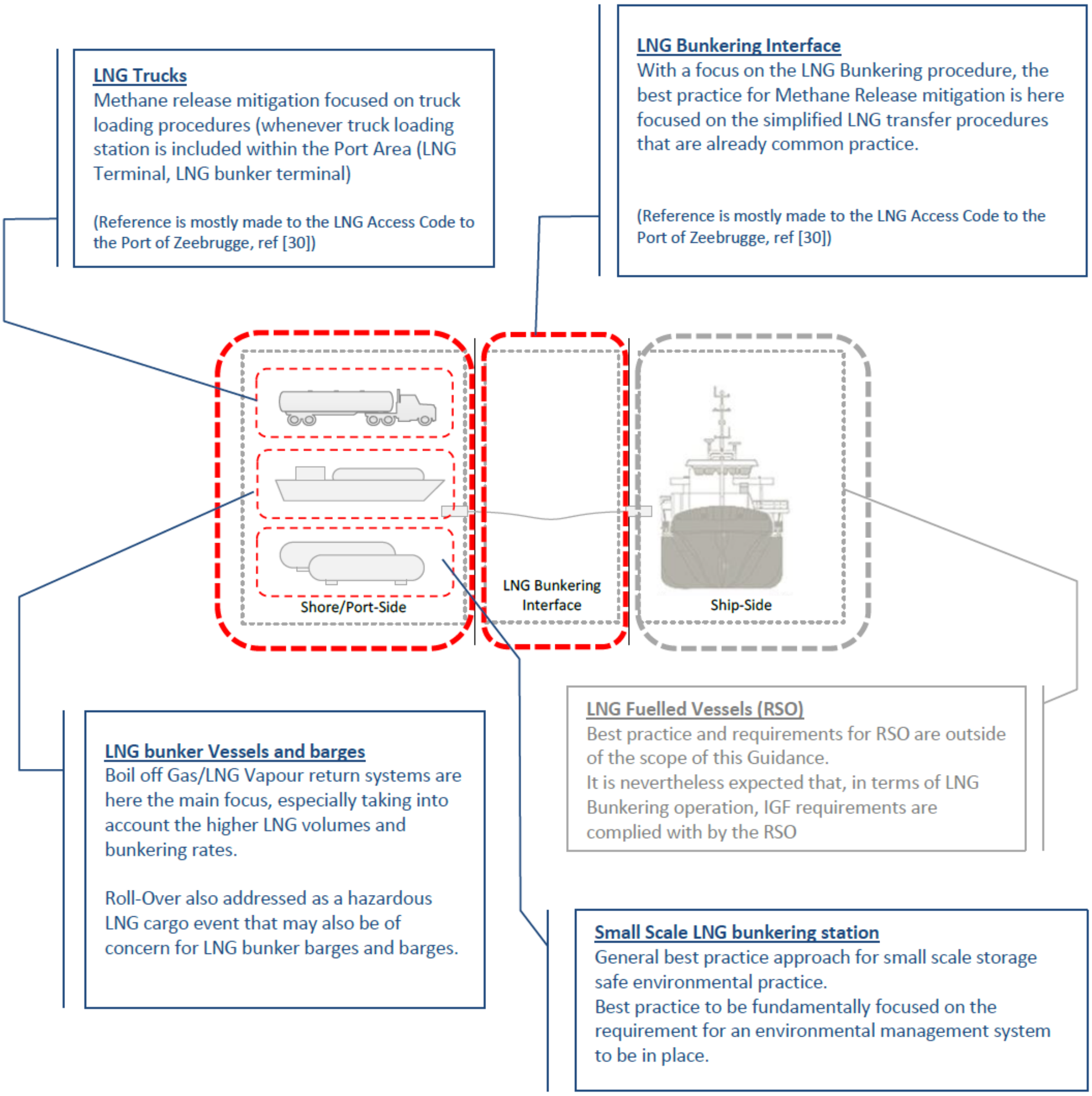


Table 3.6 EMSA main considerations for BOG handling by supply mode. Source: EMSA, January 2018

EMSA Guidance does highlight the fact that the RSO is not considered in their proposed mitigation actions, as it is expected to comply with the IGF Code requirements, and in particular with its paragraph 8.5.2. that requires the bunkering system on board the ship to *be so arranged that no gas is discharged to the atmosphere during filling of storage tanks*.

EMSA recommends that this very important requirement for the Receiving Vessel is also extended to the whole bunkering scope, not only the filling of storage tanks.

EMSA also recommends that the same concern, and limitation, should be extended to the connection and disconnection procedures, including purging and inerting of bunker lines.

Finally, EMSA recommends that in view of the importance to minimise the environmental impact of LNG bunkering operations at Ports, the LNG vapours are adequately managed at all stages of LNG bunkering operations. In order to emphasize the methane emissions control in the licensing processes of the BFO, all these recommendations should be included in the LNG Bunkering Management Plan.

3.6. LNG measuring mechanism: Quality and Quantity

It is important to understand that LNG is both a gas at source and a gas at the time of consumption and not a liquid. The gas is liquefied simply to facilitate a more efficient and commercially viable mode of transportation to market from source to storage prior to its usage as a gas, noting that in a liquid form it takes about one six hundredth of the volume of its gaseous form.

Gas purity is important when liquefying, which can only be practically carried out with the cleanest of gasses, requiring therefore the removal of impurities such as sulphur, CO2, water and mercury resulting in a product high in pure methane. When one talks about LNG quantity and quality one is actually talking about gas energy and gas quality.

Although LNG is liquid when transported and stored, its application is - which must not be confused, - as a gas for energy use such as land-based electricity and gas grids and now the growing, 'gas as bunker fuel market'. Its liquid state as bunker fuel being a means to an end to transport it to ships as fuel in a commercially viable manner and for receiving ships to store it effectively on-board as a liquid within a storage facility that can be accommodated on board without unreasonable loss of cargo carrying capacity, before transferring it into the engine consumers as gas fuel.

LNG specification standard:

ISO 23306:2020 Standard specifies the quality requirements for Liquefied Natural Gas (LNG) used as a marine fuel for marine applications. It defines the relevant parameters to measure as well as the required values and the test reference methods for all those parameters.

According to ISO, this document applies to LNG from any source, e.g. gas from conventional reservoirs, shale gas, coalbed methane, biomethane, synthetic methane.

LNG described in this ISO document can come from synthesis process out of fossil fuels or renewable sources.

The ISO document identifies the required specifications for fuels delivered at the time and place of custody transfer (at the delivery point).

Methane Number:

The methane number is a measure of the resistance of natural gas to detonation (i.e. knock resistance) when it is burned as a fuel in an internal combustion engine. Pure methane which rarely exists in commercial form is assigned a methane number of 100, while hydrogen selected for its very poor knock resistance is assigned a methane number of zero. Usually a methane number above 80 is desired to avoid all knocking.

The calculation of the methane number would be simple if the gas only consists of two components i.e. methane and hydrogen. However, all variants of commercial LNG will contain heavier components such as ethane, propane (heavier gases) including traces of nitrogen given its role of inerting transfer piping when not in use.

There are two standards for calculating the methane number: ISO 23306 and EN 16726, in addition to majority of engine manufacturers who have developed their own proprietary methods (e.g. MAN, Wartsila, Caterpillar, Cummins). Therefore, each approach is different from the others resulting in an ongoing controversy on how to estimate the methane number and setting a minimum requirement for LNG suppliers.

It is a recommended good practice that prior to LNG bunkering there is clarity between the supplier and buyer that the minimum allowable methane number of the LNG to be supplied complies, as a minimum, with the prescription of the receiving engine's OEM (Original Equipment Manufacturer). This is also a typical requirement from the OEMs. Such minimum value is normally found published on the Engine's Operating and Maintenance Manuals issued by the engine's maker.

The bunker supplier could consider the possibility to fit Gas Chromatograph Mass Spectrometer (GC MS) fitted, in order to perform a LNG quality check at delivery point, as current industry best practice.

LNG quantity measurement methods:

The quantity of LNG could be determined by the static metering system, like Weighbridge or by dynamic metering systems, line the Coriolis mass flow meter (MFM) and/or by LNG volumetric (ultrasonic) flow meters which are being gradually introduced into applications of LNG mass measurement.

Coriolis meters are reported to measure mass flow directly; these meters are also reported to have better accuracy than volumetric (ultrasonic) flow meters, however they are also reported to have size and pressure limitations. On the other hand, installation of straight pipes upstream and downstream is reported by industry users/adopters not being required, reducing pipe length and installation costs compared to ultrasonic flowmeters. In both cases, it is recommended that the quantity measurement equipment is:

a. Calibrated to comply with a maximum permissible error that could be set, for example, in accordance with the recommendations of the Organisation Internationale de Métrologie Légale OIML (International Organisation of Legal Metrology), in particular with OIML R76 for Weighbridge and OIML R117-1 for MFM.

b. Calibrated at an established frequency:

    a. for weighbridge this could be set annually and in any case at the required more frequent intervals that secures the system to work below the maximum permissible error at all times.

    b. In the case of MFM/ultrasonic instrument, the calibration frequency is recommended to be once every three years so that the error for measurement of LNG could fall within the maximum permissible error of 1%. However, it would be considered the user's responsibility to assess whether the next calibration is required to be perform earlier, considering the operating conditions. It is recommended that the MFM zero conditions are verified regularly to ensure that the equipment is set not to exceed the maximum permissible error.

    c. It is recommended that the weighbridge and MFM are type approved and in compliance with OIML76 and OIML R117-1 respectively.

3.6.1. LNG custody transfer reporting on quality and quantity

For LNG Bunkering in the port, the Port Authority should ensure, as minimum, that a Bunker Delivery Note (BDN) is issued to the Receiving Vessel stating the quality composition of the LNG supplied, its Sulphur content and Methane number, as well as relevant quantities, and the means of measuring the latter.

It is also recommended that the Port Authority requires regular information from the BFO about the quantities delivered.

Regarding to the content of the LNG custody transfer Report, details of requirements are given in Annex 1.

Regarding contractual requirements, the Port Authority could refer to detailed guidance contained on the SGMF Quality and Quantity Contractual Guidelines ISBN 97800 – 9933164-1-8. This Guideline is very comprehensive and best reference for Port Authorities, covering all aspects of Q&Q, issued in 2017.

4. LNG Bunkering Regulatory Analysis and Guidelines

Regulation (EU) 2017/352 of the European Parliament and of the Council of 15 February 2017 established the framework for the provision of port services and common rules on the financial transparency of ports. At a national level, TRLEPMM established the regulatory framework regarding to port services.

. The current guidelines involve and apply to LNG bunkering operations, concerning the refuelling/bunkering of a LNG receiving vessel (RSO) from a LNG Bunkering Vessel or LNG Bunkering Barge (LBB) or from a mobile facility or from a bunkering terminal. They are the basic reference for Port Authorities to develop their own procedures and conditions for the LNG bunkering service.

There is a vast myriad of existing international regulations, standards and guidance related to the use of LNG as a bunkering fuel for ships.

4.1. Main regulatory framework

4.1.1. Seveso III Directive and Spanish RD 840/2015

In 1976 a subsidiary of the Roche group operating in the Italian town of Seveso experienced a catastrophic accident resulting in the release of toxic chemicals, exposing the local population. This event prompted the adoption of legislation to regulate the safety of large amounts of dangerous substances. In its current form, the Seveso III directive, Directive 2012/18/EU of 4th July 2012, requires the LNG bunker provider(s) to identify and manage risks in order to prevent failures and accidents including a structured emergency response should failures materialise.

As part of the site (Port) feasibility assessment, the Port Authority should evaluate the applicability of Seveso III directive to determine if aggregated bunkering operations can be categorized as:

1. Seveso III exempt,
2. Seveso III lower tier or,
3. Seveso III upper tier.

The interpretations for reviewing LNG bunkering against the Seveso III directive is discussed at some length in Chapter 4.2 (High Level Instruments) of the EMSA Guidance on LNG Bunkering to Port Authorities.

However, the EMSA guideline falls short in recommending an approach to assess the envisaged LNG bunkering operations against the different Seveso categories (i.e. exempt, lower tier, higher tier). Recognising this gap, LR has developed its own guidance for Port Authorities, as shown on Table 8.1.

Spanish Royal Decree 840/2015 dated 20th October 2015 approves the control measures of risks inherent to accidents related to dangerous goods, by incorporating the European Union Directive 2003/105/EC of 16th December 2003 modifying Directive 96/82/EC (also known as “Seveso II Directive”), of 9th December 1996, and transposing all the remaining provisions of Directive 2012/18/UE.

4.1.2. European Agreement concerning the International Carriage of Dangerous Goods by Road, “ADR”

The Agreement concerning the International Carriage of Dangerous Good by Road (ADR) was done at Geneva on 30th September 1957 under the auspices of the United Nations Economic Commission for Europe, and it entered into force on 29th January 1968.

The key article is the second, which says that apart from some excessively dangerous goods, other dangerous goods may be carried internationally in road vehicles subject to compliance with:

the conditions laid down in Annex A for the goods in question, in particular regarding their packaging and labelling, and the conditions in Annex B, in particular regarding the construction, equipment and operation of the vehicle carrying the goods in question.

Both Annexes have been regularly amended and updated since 1968. The latest update entered into force on 1 January 2021, a revised consolidated version that is published as document ECE/TRANS/300, Vol. I and II and Corr.1 and Corr.2 (ADR 2021).

4.1.3. EIA Directive (2011/92/EU as amended by Directive 2014/52/9EU)

The Environmental Impact Assessment (EIA) is a framework for evaluating new projects (e.g. assets, facilities, operations) that can have significant effects on the environment. There are two general categories of projects, based on the overall impact of the project on the environment.

Projects listed in Annex I are considered as having significant effects on the environment and require an EIA (e.g. long-distance railway lines, motorways and express roads, airports with a runway length greater than 2100 m, installations for the disposal of hazardous waste, etc.)

Next are the types of projects listed in Annex II, were the national authorities have to decide whether an EIA is needed. Projects listed in Annex II to the Directive are not automatically subjected to an environmental impact assessment. Member States can decide to subject them to an assessment on a case-by-case basis or according to thresholds and/or criteria such as location (i.e. proximity to sensitive ecological areas) and potential impact. The process of determining whether an assessment is required for a project listed in Annex II is called screening. In determining thresholds or assessing the effects of projects, the relevant selection criteria set out in Annex III to the Directive should be taken into account. In particular, the screening process should not be based on one criterion only (e.g. size), but it should take into consideration all the relevant selection criteria listed in Annex III (e.g. not only size but also the location of the project).

"Energy Industry" projects such as gas storage infrastructure i.e. including LNG bunkering form part of Annex II. This requires the relevant national authorities in Spain to decide whether an EIA is needed for each port depending on the envisaged bunker volumes and other factors required by the screening process in Annex III.

4.1.4. EU Directive 2017/352/EU framework for the provision of port services

This directive establishes a framework for the provision of port services and common rules on the financial transparency of Ports.

Bunkering is considered a "Port service" under this Directive. And bunkering definition includes the provision or liquid or gaseous fuel used for the propulsion of waterborne vessels as well as for general and specific energy provision on board waterborne vessels whilst at berth.

The Directive requests that the managing body of the Port, or the competent authority, should be able to require that providers of port services are able to demonstrate that they meet minimum requirements for the performance of the service in an appropriate way, and that are able to demonstrate their ability to serve a minimum number of vessels, making available the necessary staff and equipment.

The Directive also indicates that Member States should be able to require compliance with obligations in the field of social and labour law for the operation of port services in the port concerned.

4.1.5.EU Directive 2014/94/EU on the deployment of alternative fuels infrastructure

This Directive includes "natural gas, including biomethane, in gaseous form (compressed natural gas (CNG)) and liquefied form (liquefied natural gas (LNG))" as an alternative fuel, among others.

The Directive states that for LNG, a core network of refuelling points for LNG at maritime and inland ports should be available at least by the end of 2025 and 2030 respectively.

The Directive also indicates that refuelling points for LNG include, inter alia, LNG terminals, tanks, mobile containers, bunker vessels and barges.

The Directive recognises that the IMO develops uniform and internationally recognised safety and environmental standards for maritime transport, and that conflicts with international standards should be avoided in view of the global nature of maritime transport. The Directive calls for the adoption of European Standards that are based on current international standards or ongoing international standardisation work, where applicable, such as ISO/DTS 18683 for maritime.

The Directive refers to requirements for interfaces of bunker transfer of LNG in maritime and inland waterway transport, and requirements for safety aspects of the onshore storage and bunkering procedure of LNG in maritime and inland waterway transport.

4.2. Standards

Link between high level instruments and the operational or technical implementation of their provisions. Published by international standardization bodies (ISO, CEN and IEC). Needed to ensure compatibilities across the globe. Standards are voluntary which means that there is no automatic legal obligation to apply them. However, laws and regulations may refer to standards and even make compliance with them compulsory.

There are many standards related to the safety of systems, applications, transportation, handling of gas, and the ones that are most significant and specific to LNG bunkering safety are the ISO/TS 18683 and the ISO/IS 20519.

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

This standard:

Gives guidance on the minimum requirements for the design and operation of the LNG bunkering facility and necessary risk assessments, including the interface between the LNG supply facilities and receiving ship.
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.
Applicable to bunkering of both seagoing and inland trading vessels. It covers LNG bunkering from shore or ship LNG supply facilities and addresses all operations required such as inerting, gassing up, cooling down, and loading.

4.2.2. ISO/IS 20519: LNG Bunkering operations in Ports: Specification for bunkering of liquefied natural gas fuelled vessels

EN ISO 20519 is referred throughout this Guidance as the standard that should serve as a basis for certification, accreditation, and quality assurance of all stakeholders. The EN notation is essential to ensure that, at least in the EU, the standard is incorporated by all EU Member States as a national standard.

This standard represents an instrument of direct support to the IGF Code, providing the frame work for implementation of IGF Code.

Section 18.4 provisions on bunkering operations.

ISO 20519:2017 sets the requirements for LNG bunkering transfer systems and equipment used to bunker LNG fuelled vessels, which are not covered by the IGC Code. This document includes the following five elements:

Hardware: liquid and vapour transfer systems;
Operational procedures;
Requirement for the LNG provider to provide an LNG bunker delivery note;
Training and qualifications of personnel involved;
Requirements for LNG facilities to meet applicable ISO standards and local codes.

4.2.3. ISO 21593:2019 Ships and marine technology — Technical requirements for dry-disconnect/connect couplings for bunkering liquefied natural gas

The document specifies the design, minimum safety, functional and marking requirements, as well as the interface types and dimensions and testing procedures for dry-disconnect/connect couplings for LNG hose bunkering systems intended for use on LNG bunkering ships, tank trucks and shore-based facilities and other bunkering infrastructures. [Note: The document is not applicable to hydraulically operated quick connect/disconnect couplers (QCDC) used for hard loading arms, which is covered in ISO 16904.]

4.2.4. ISO/IS 28460:2010 Petroleum & Natural Gas Industries – Installation & Equipment for LNG – Ship to Shore interface and Port operations

Also applicable to bunker suppliers, lubricants and service providers while the LNG Carrier alongside a terminal.

Applicable to LNG ship and terminal operators, pilotage and vessel traffic services.

Danish Maritime Authority (DMA) carried out detailed study of ISO 28460 in terms of its suitability for LNG bunkering. The study concluded that the LNG bunker tanker can be considered similar to other dangerous cargo and the standard may also be applicable for LNG vessels and barges with minor modifications.

Section 2,3 & 4 of the standard apply to LNG bunkering procedures.

Noteworthy provisions are as follows: Hazardous situations associated with LNG transfer; Ship/shore interface and port operations; Hazardous areas & electrical safety; Hazard management; Vessel's safe transit; Berthing and mooring; Cargo transfer; Instrumentation across interfaces; Liquid N2 connections; Firefighting (ship & terminal) and Training.

This is considered a good reference document for developing the bunkering standards as even small details e.g. pin configuration for SSLs are covered.

Section 8.4.1, 8.4.2 & 8.4.5 of the standard on mooring requirements should include all types of receiving vessels.

Sect 8.4.10 cited stopping of other activities during cargo operations (Implying bunkering operations).

4.2.5. ISO/IS 31010: Risk Assessment Techniques

This standard contains and overview of and contents of a Risk Assessment, Methodologies, Risk Identification, Analysis and Mitigation, Risk Evaluation, Applications, Types of Techniques, Criteria Matrix, Probabilities, HAZID / HAZOP, Documentation and follow up after assessment.

4.2.6. ISO23306:2020 Specification of liquefied natural gas as a fuel for marine applications

This standard specifies the quality requirements for Liquefied Natural Gas (LNG) used as a marine fuel for marine applications. It defines the relevant parameters to measure as well as the required values and the test reference methods for all those parameters.

According to ISO, this document can be applied to LNG from any source, e.g. gas from conventional reservoirs, shale gas, coalbed methane, biomethane and synthetic methane.

LNG described in this ISO document can come from synthesis process out of fossil fuels or renewable sources.

The ISO document identifies the required specifications for fuels delivered at the time and place of custody transfer (at the delivery point).

4.2.7. Installations and Equipment for LNG (Design and Testing of Marine Transfer Systems)

This standard has been implemented across Europe.

The standard consists of 3 parts as follows:

- Part 1: Design & Testing of Transfer Arms (replaced by EN 16904:2016)
- Part 2: Design & Testing of Transfer Hoses, EN 1474-2:2008 and EN 1474-3:2008
- Part 3: Offshore Transfer Systems

The standard provides: design and material selection, minimum safety requirements, inspection & testing procedures for LNG transfers between ship and shore, and requirements for remote control power stations.

Contents of the standard do not include all details for design and fabrication of standard parts.

The standard can be considered as supplementary to regulations and requirements of EN-ISO 28640.

4.3. International Maritime Codes and Rules applicable to Gas Carrier Ships and Gas Fuelled Ships

4.3.1. International Code for the Construction and Equipment of Ships carrying liquefied gases in bulk (IGC Code)

The IGC Code applies to Gas Carriers constructed on or after 1 July 1986. However, Gas Carriers constructed prior to this date should also comply with requirements set by the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk or the Code for Existing Ships Carrying Liquefied Gases in Bulk. All these codes are issued by the IMO (International Maritime Organisation).

The purpose of these codes is to provide an international standard for the safe transport by sea in bulk of liquefied gases and certain other substances, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimise the risk to the ship, its crew and to the environment, having regard to the nature of the products involved.

It is requirement of the Spanish Maritime Administration to apply the IGC Code to all LBBs and LBVs.

4.3.2. International Code of Safety for Ships using gases or other low-flashpoint fuels (IGF Code)

The purpose of the IGF Code is to provide an international standard for ships, other than vessels covered by the IGC Code, operating with gas, including LNG, or low-flashpoint liquids as fuels.

The Code provides mandatory criteria for the arrangement and installation of machinery, equipment and systems for vessels operating with gas or low-flashpoint liquids as fuel to minimise the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved.

RVs must comply with the requirements set by the IGF Code, or with the requirements of the IGC code in case the ships are categorised as Gas Carriers as defined by the IGC Code.

4.3.3. International Maritime Organization IMO: STCW

The International Convention on Standards of Training, Certification and Watchkeeping (STCW) for Seafarers, 1978, sets the minimum qualification standards for masters, officers and watch personnel on seagoing merchant ships and large yachts to which the IMO's regulations apply.

IMO Resolution MSC.396(95) adopted on 11th June 2015 amended the STCW 1978 Convention introducing requirements for personnel that work on ships that are subject to the IMO IGF Code, gas-fuelled ships included.

These requirements are applicable to ship's personnel involved in all modes of LNG bunkering when a ship is involved: STS, TTS and PTS bunkering operations.

The STCW Chapter V refers to "Special training requirements for personnel on certain types of ships" and includes gas-fuelled ships among such types.

STCW Regulation V/3 of Chapter V details what the minimum requirements are for the training and qualification of masters, officers, ratings and other personnel on ships subject to the IGF Code.

And STCW Code Section A-V/3 of Chapter V specifies Basic Training (in its Table A-V/3-1) and Advanced Training (in its Table A-V/3-2) and the standard of competencies required.

4.3.4. International Safety Management Code (ISM Code)

The purpose of this IMO Code is to provide an international standard for the safe management and operation of ships and for pollution prevention.

Safe management and operation of ships includes the avoidance of damage to the environment with focus on the marine environment and on property as one on its main objectives; the Code establishes safety management objectives of ship managing companies in order to secure this main objective:

- Provide safe practices in ship operation and working environment,
- Establish safeguards against all identified risks; and,
- Continuously improve safety management skills of personnel ashore and onboard ships. These skills include the preparation for emergencies related to safety and environmental protection.

The ISM Code covers LNG bunkering operations for ships that are involved in them and are mandated to comply with the Code.

4.3.5. Rules from members of IACS (International Association of Classification Societies)

The IACS members publish rules and regulations for the classification of ships carrying liquefied gases in bulk as well as for ships using gases or low-flashpoint fuels. IACS has adopted the requirements of the IGC Code and the IGF Code respectively for such ships; therefore, RVs, LBBs and LBVs that are built to comply with IACS Rules will, in general, also comply with the applicable requirements of the IGC and / or IGF Codes.

International Association of Classification Societies (IACS): IACS Rec. 142

IACS published its LNG Bunkering Guidelines in June 2016, a joint effort of a working group of experts selected from several of the IACS' members.

These IACS guidelines are particularly useful to compile LNG Bunker Management Plans, specify key personnel's roles and their accountability and responsibility, and offers recommendations on bunkering process, SIMOPS, safety zones and risk assessments, in addition to technical requirements for bunkering systems.

IACS Rec 142 is mentioned and integrated into the SGMF LNG Bunkering Guidelines, as most of the IACS members are also members of SGMF and contribute actively in working groups that generate SGMF's publications.

4.4. Industry Guidance

There are published guidance that are considered of high value in supporting Port Authorities and all stakeholders involved in LNG bunkering at Ports to become aware of best practices and other recommendations regarding safety of gas handling, transportation and bunkering operations; all have been produced by recognised organisations within the maritime industry. We would recommend to be guided by the following publications:

4.4.1. European Maritime Safety Agency (EMSA): Guidance on LNG Bunkering to Port Authorities and Administrations, 31st January 2018

The European Maritime Safety Agency (EMSA) has written a very detailed document, Guidance on LNG Bunkering to Port Authorities and Administrations which provides a great amount of information on best practice control measures for LNG bunkering, and small-scale LNG storage, relevant to Port Authorities-

Administrations in their role on permitting, evaluating, approving, certifying, controlling, overviewing, documenting and providing/coordinating response in case of emergency.

The guidance document latest edition dated 31st January 2018 also contains detailed guidance mainly for small scale LNG bunkering and it is regarded very useful for all Ports. It contains a specific section for infrastructure within Ports and Floating Storage Units FSU's.

This guidance is considered of high value as it is one of the most comprehensive publications a safety agency has produced in the maritime industry; it is an established and recognised reference for all marine stakeholders in the LNG supply chain and this Guide makes reference to relevant sections when considered of added value.

4.4.2. The Society for Gas As a Marine Fuel (SGMF): LNG Bunkering Guidelines

The Society for Gas As A Marine Fuel (SGMF), has issued a series of relevant publications, produced in close collaboration with gas supply chain maritime stakeholders globally; their publications bring in the member's best practices with regards to operating with gas, and in particular with natural gas and LNG.

A list of most significant areas where recommendations on best practices are made are:

- **Gas as a Marine Fuel**: Work practices for maintenance, repair and dry dock operations: the document provides guidance on work practices for maintenance, repair and dry-dock operations for ships that use gas/LNG as fuel to help ensure the safe maintenance of gas-fuelled ships.
- **LNG bunkering with hose bunker systems: considerations and recommendations:** the document provides recommendations for the safe handling and operation of hose bunker systems utilizing cryogenic flexible hoses as the main means for LNG transfer. It specifically addresses hose selection and its handling and functional safety principles.
- **Recommendations for linked emergency shutdown (ESD) arrangements for LNG bunkering**: the document provides recommendations for the Emergency Shutdown System arrangements, integration, data and voice communication and interfaces for the LNG bunkering of gas-fueled vessels. It specifically addresses the functional safety principles of the linked ESD system to ensure a controlled shutdown of the bunkering operation in the case of an emergency.
- **Manifold arrangements for gas-fuelled vessels:** this document is intended to facilitate focused discussion and industry alignment on the manifold arrangement fitted on board gas-fuelled vessels. A standardized Manifold Form to facilitate the compatibility has been also released.
- **Recommendation of Controlled Zones during LNG bunkering**: the publication details how to effectively determine the location and size of so-called controlled zones around the bunkering equipment itself. Associated to the document, an automated tool has been created. This is "BASiL Gas Dispersion Tool". BASiL (Bunkering Area Safety information LNG) can be used to manage bunkering on a consistent basis through the definition of a safety zone that depends on the type of bunkering operation being undertaken.
- **Simultaneous Operations (SIMOPs) during LNG Bunkering:** the document looks at undertaking typical ship operations in port whist transferring fuel at the same time (SIMOPS). The document explains how to address the safety issues involved and describes clearly the process of how the risks can be managed.

And the **SGMF publication FP04-02 Version 2.0 related to Training and Competence** of personnel involved in bunkering of ships with LNG is particularly of value for organisations to produce their own requirements for the personnel that are to be accountable and responsible for the safe bunkering of LNG to ships within the organisation's scope of LNG bunkering operations.

4.4.3. International Association of Ports and Harbors (IAPH): WPSP LNG Bunkering Tools

The IAPH claims to be "The global voice for the Ports of the world", and states that being a member of the IAPH gives the ports of the world a way to represent themselves on a global scale.

As per its current website, the IAPH was formed on November 7th, 1955 when some 100 delegates from 38 ports and maritime organizations in 14 countries gathered in Los Angeles. Over the past six decades, IAPH has steadily developed into a global alliance of ports, representing today some 180 ports and some 140 port-related businesses in 90 countries. The member ports together handle well over 60% of the world's sea-borne trade and nearly 80% of the world container traffic. It is a non-profit-making and non-governmental organization (NGO) headquartered in Tokyo, Japan.

Recognized as the only international organization representing the voice of the world port industry, IAPH is granted Consultative Status as Non-governmental Organization (NGO) from five United Nations (UN) specialized agencies and one intergovernmental body[3]:

The consultative status has enabled IAPH to represent at international fora the views of port managers/directors and promote, enhance and protect the interests of the global port industry as a whole. The principal aim of IAPH revolves around promotion of the interests of Ports worldwide, building strong member relationships and sharing best practices among the members.

World Ports Sustainability Program WPSP

On 12 May 2017 the IAPH decided to set up a World Ports Sustainability Program. Guided by the 17 UN SDGs (United Nations Sustainability Development Goals) the WPSP builds on the World Ports Climate Initiative WPCI that IAPH started in 2008 and extends it to other areas of sustainable development.

The IAPH is a founding member of the World Ports Sustainability Program WPSP, which has the mission to demonstrate global leadership of ports in contributing to the Sustainable Development Goals of the United Nations.

The WPSP Clean Marine Fuels working group aims at offering ship owners as broad a spectrum of alternative fuels as possible in order to improve air quality and reduce greenhouse gas emissions in and around ports and harbours. The working group involves standard agencies, industry associations, classification societies, oil majors, terminals, bunker operators and ship owners in the process of acquiring unique insights into alternative clean marine fuels and applying them in practice for bunkering at ports.

This working group has created practical tools for ports that facilitate safe and efficient LNG bunkering operations in ports for all existing and upcoming clean marine fuels covered under their scope of work, and LNG is one of such fuels.

Among such tools, the WPSP Clean Marine Fuels working group has created:

- **LNG Bunkering Checklists**, a harmonised set of checklists for known LNG bunkering scenarios that reflect the extra requirements of ports with regards to LNG bunkering operations in or near their port environment. According to the IAPH, by using their checklists, the operator can obtain a high level of quality and responsibility of the LNG bunkering operation. We do recommend the adoption of these checklists in this Guide, as best practice in the industry. The implementation of harmonized LNG bunkering checklists in Ports will also be of great benefit to the RVs and their crew when bunkering LNG in other Ports because, according to the WSPS, it will reduce the potential confusion caused by having to comply with different rules and regulations in different ports.

[3] UN Economic and Social Council (ECOSOC)
International Maritime Organization (IMO)
UN Conference on Trade and Development (UNCTAD)
UN Environment Programme (UNEP)
International Labour Office (ILO)
World Customs Organization (WCO)

- **Audit Tool,** a software tool supporting an online service for ports to check compliance with the IAPH LNG Bunker Supplier Accreditation Model.
- **LNG Terminal Readiness,** The IAPH LNG Ready Terminal Guidance is considered yet another positive step towards raising higher levels of awareness of all parties involved in the LNG bunkering operations of the role of Terminals and Ports in the safe operation of LNG bunkering at Ports. The new guidance is a tool for Port authorities to establish a safety framework for new marine fuels in their Ports, and for the preparedness of Terminals at the same time. However, the IAPH states that Terminal safety management systems and the results of safety studies carried out by Terminals can always take precedence over their LNG Ready Terminal guidance.

IAPH LNG Ready Terminal Guidance and checklists

Recognizing the importance of the Terminal in the safe operation of LNG bunkering within Port, the IAPH has, as of September 2020, created a new guidance for Terminals, and created the term "LNG Ready Terminal".

According to the IAPH: "the increasing uptake of LNG-fuelled newbuild and retrofitted vessels means terminals need to be ready to receive them and to be able to do safe cargo handling during LNG bunkering operations". Although these vessels are safe by design, terminals need to prepare by reviewing their existing (terminal – vessel interface) safety procedures given the risk level associated with this fuel compared to conventional fuel types.

This will enable terminals to qualify as "LNG-ready terminal", i.e. a terminal that has successfully aligned the procedures of its safety management system, the skills of its personnel and the preparedness of visitors such that it may handle LNG-fuelled vessels in a safe way."

As stated by IAPH, their guidance details procedures and operational preparedness actions of terminals to assure a safe handling of LNG-fuel vessels, including a safe ship to ship bunkering of LNG fuel vessels alongside the terminal.

The guidance is created to complement their existing checklists and supporting instruments, as shown in Figure 4.1 below.

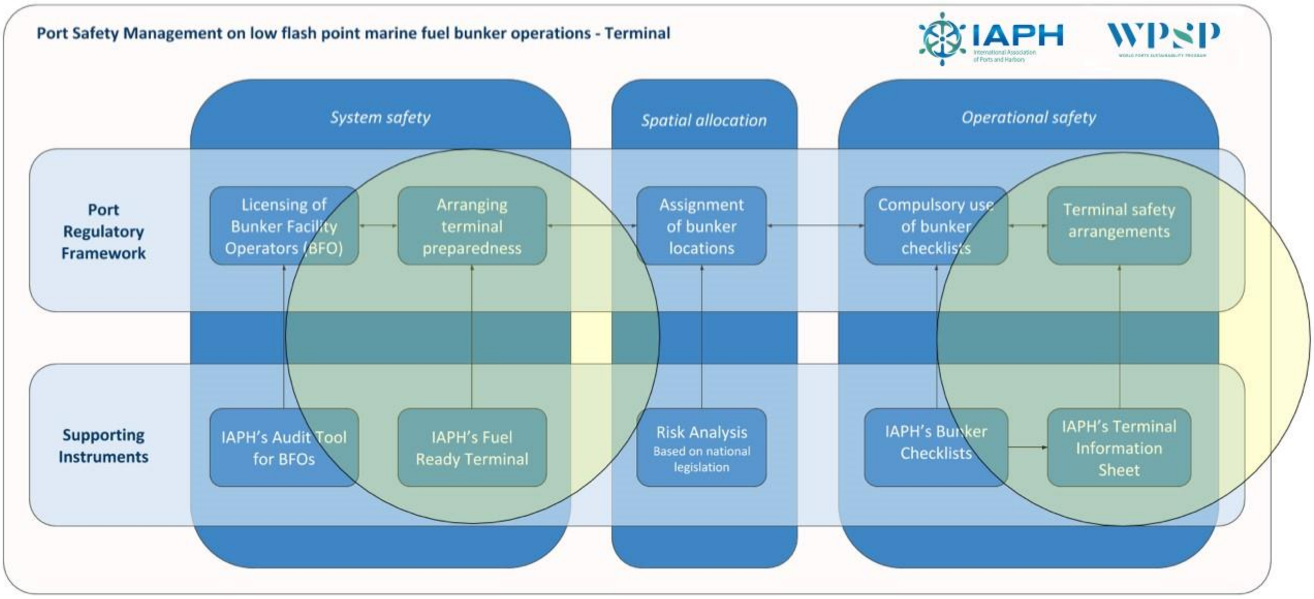


Figure 4.1 IAPH LNG ready terminal guidance implications on LNG bunkering permitting. Source: IAPH, 2020

The IAPH LNG Ready Terminal Guidance is considered yet another positive step towards raising higher levels of awareness of all parties involved in the LNG bunkering operations, of the role of Terminals and Ports in the safe operation of LNG bunkering at Ports.

The new guidance is a tool for Port authorities to establish a safety framework for new marine fuels in their Ports, and for the preparedness of Terminals at the same time. However, the IAPH states that Terminal safety management systems and the results of safety studies carried out by terminals can always take precedence over their LNG Ready Terminal guidance.

The guidance could be considered a new management tool for the creation of Terminal's safety management procedures for LNG bunkering operations within their premises, that can easily align with the procedures and conditions set by individual RVs and LBVs bunkering management plans, creating a potential clear link between ship specific safety requirements and the ability of Terminals to comply with them.

The guidance examines how Terminals would comply with the requirements of safe LNG bunkering on what the IAPH calls "a project-based safety approach", when the Terminal is fully involved in the arrangements made between the terminal, the RSO and the LBV, such that a so-called "Joint Plan of Operation (JPO)" could be established and adopted by all parties.

It also examines how Terminals would follow a "system-based approach" to become "LNG Ready", in case they deal with several RVs and LBVs and PSPs, where a more flexible approach will be necessary as Terminals may not engage with vessels at very early stages of vessels' preparation for bunkering. A system-based preparedness by these Terminals will often be preceded by a project-based preparedness and experience.

It would appear that the ultimate aim of IAPH's new LNG Ready Terminal Guidance is to reduce the risk of misalignment between RVs and LBVs bunker management plan requirements and the Terminal's ability to comply with them. This is considered a great step forward towards securing higher levels of safe LNG bunkering operations within Ports.

The IAPH LRT concept seems to represent a new way for Terminals to have a self-check guide containing all possible measures a Terminal would consider taking to assure a safe operation of LNG bunkering within its premises. This new framework could accelerate a Terminal's own self-check prior to requesting its operating license and represent their real level of readiness to comply with PA and other competent authority requirements.

The guide helps Terminals to also consider their level of maturity to reduce or eliminate potential compliance and safety gaps they may encounter when unscheduled or unfrequently visiting RVs call at their premises requiring a LNG bunkering operation. As the LNG Fuel fleet increases globally, it seems of value for Terminals to self-check themselves against the IAPH's so called "system-based approach" involvement on LNG bunkering.

4.4.4. International Safety Guide for Tankers and Terminals - ISGOTT

The Oil Companies International Marine Forum (OCIMF) and the International Chamber of Shipping (ICS) together with the IAPH have revised and updated the ISGOTT Guide and issued its Sixth Edition in 2020.

The Guide provides relevant information on: Jetty topsides (operation, inspection and maintenance), marine hoses, emergency shutdown devices, LNG manifolds, Ship To Ship (STS) loading for LNG carriers.

The Sixth Edition encompasses the latest thinking on a range of topical issues including gas detection, marine and terminal administration and the critical importance of the tanker/terminal interface, bunkering operations including the use of alternative fuels such as LNG.

The guide also provides a Ship/Shore Safety and Bunkering Operations Checklist revised to reflect changes in the understanding of the impact of human factors in their effective use, so that to ensure the individual and joint responsibilities for the tanker and the terminal are clearly communicated before ship's arrival to terminal, as well as while ships are alongside.

The following checklists are available and free to download at OCIMF website:

ISGOTT Bunker checklist: pre-arrival
ISGOTT 6 MOC
ISGOTT 6 Ship Shore Checklists

4.4.5. NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)

The National Fire Protection Association (NFPA) is a global self-funded non-profit organisation, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards, and it is widely known as a codes and standards organisation.

Their NFPA59A Standard provides minimum fire protection, safety and related requirements for the location, design, construction, security, operation and maintenance of LNG plants

The standard includes requirements for the following in gas plants:

Piping, valves, pressure vessels, gauges, equipment, building and structures, relief valves, operations, maintenance and protection, safety and security.

4.4.6. World Association for Waterborne Transport Infrastructure, PIANC

PIANC, established in 1885, is a global organisation providing guidance and technical advice for a sustainable waterborne transport infrastructure to ports, marinas and waterways.

Its content includes requirements for:

Channel design and concept design method (depth, width, alignment, calculations, width and radius)
Other aspects also considered include navigation, manoeuvring, traffic, capacities, wave studies and use of tugs.

The PIANC has a Memorandum of Understanding signed with the IAPH as "Sister Association".

4.4.7. The Society of International Gas Tanker and Terminal Operators, SIGTTO

SIGTTO is a not-for-profit organisation, founded in 1979 and based in London, UK. It 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. SIGTTO guidelines are very well regarded among the industry, in particular, by stakeholders of the gas maritime supply chain.

SIGTTO's LNG Ship To Ship Transfer (STS) Guidelines was first issued in 2011, and revised in 2013 as Ship To Ship Transfer Guide for Petroleum, Chemicals and Liquefied Gases.

The Guidelines directly address LNG side by side STS transfer between LNG carriers at anchor, alongside a shore jetty or underway.

This Guideline is a useful reference in establishing rules and procedures for transfer operations between sea-going ships, LNG re-gasification vessels (FSRU) and LNG Floating productions units (FLNG), as well as for developing procedures to facilitate emergency STS transfer operations, when one of the vessels involved is disabled or aground.

The guidelines have been prepared with regards to technical and safety considerations.

At the time of issuing the first edition in 2011, SIGTTO members recognised the complexity of LNG STS transfer operations and strongly advised that thorough risk assessments were carried out in addition to following prescriptive requirements from their written document.

The 2013 Edition of the Guide provides advice for Masters, Marine Superintendents and others, such as STS service providers and transfer organisers, involved in the planning and execution of STS operations. It provides recommendations on safety, minimum equipment levels and good operating practices, with particular attention to the effective planning of operations and aspects including risk assessment, ship compatibility and the management of workloads to minimise fatigue.

4.4.8. Organisation Internationale de Métrologie Légale OIML

This International Organisation of Legal Metrology issues International Recommendations for the dynamic measuring systems for liquids other than water, such as equipment and systems used to determine the quantity of LNG.

Their International Recommendation OIML R117-1 Edition 2007 (E) applies to Mass Flow Meters (MGM), setting requirements for the metrological control of the equipment, including type approval, initial verification and subsequent verification, as well as type approval performance tests requirements.

Their International Recommendation OIML R76-1 Edition 2006 (E) applies to non-automatic weighing instruments.

4.5. Spanish National specific regulation

4.5.1. Consolidated Legislation: Ports and Merchant Navy – RDL 2/2011

This Spanish legislation aims at regulating the provision of commercial services within Ports (Libro Primero, Titulo VI, Capitulo V), as well as regulating the management of personnel involved in delivering such services (Libro Primero, Titulo VI, Capitulo VI).

The legislation also makes reference to requirements for emergency plans, determination of zones and activities undertaking within each zone.

Although LNG Bunkering is not specified as one such commercial service, we would recommend that above references within this legislation are considered when creating the Port's LNG Bunkering local legislation as they are directly relevant to the safety of the LNG bunkering operation activity, and that advice on how to apply this legislation to LNG bunkering is directly sought from the Spanish Administration.

Link to the consolidated legislation: https://www.boe.es/eli/es/rdlg/2011/09/05/2/con

Latest actualization published on 31 December 2020.

4.5.2. SEVESO III Directive embed in Spain legislation

Spain legislation RD 840/2015 covers Seveso III Directive compliance within Spain. This legislation mandates that the requirements set by the more recent EU Directive 2012/18 dated 4 July 2012 are applied by parties responsible for handling and storage of dangerous good, as categorised in the legislation, and LNG falls within such category.

For this reason, we recommend this guide due to the amount of LNG that could be typically handled and stored on land or on board LBBs / LBVs, and that a feasibility assessment is carried out as mandated by the Port Authority in order that the applicability of Seveso III Directive is determined, with regards to whether the aggregated bunkering operations can fall within a Seveso category for which additional safety measures are recommended. Our recommendation of applicability is detailed on Table 8.1**.**

4.5.3. **Protocols of National Spanish Gas system**

Users of LNG import terminals (reloads in truck and vessels and PTS supplies) should comply with specific regulations of the gas system stablished in Circular procedures, NGTS ("*Norma de gestion técnica del Sistema"*) and PDs ("Protocolos de detalle").

4.6. Port local regulations

Port local regulations represent the best vehicle to integrate all that is regulated regarding LNG bunkering operations plus adding specific requirements that would exist locally, as local additional regulations or local adopted best practices or similar.

[EMSA] offers a comprehensive guidance on what a local Port Regulation could include and a list of the core elements that could be considered to form the Port Regulation.

5. LNG Bunkering Risk Assessment Analysis

5.1. Introduction to risk analysis

LNG bunkering operation is in general a multi-stakeholder multi-chain operation where several parties work in an integrated manner in order to secure the overall safety of the LNG transfer from source to destination. The hazards inherent to just natural gas and liquefied natural gas add to the hazards of bunkering operations and the hazards associated to a commonly large multi-stakeholder operation, bring the need to establish methodologies that ensure a minimum level of safety is maintained throughout the process of bunkering. More so when we also consider beyond the actual transferring to include pre-bunkering and post-bunkering processes, where additional hazards to the safety of personnel involved and property around may arise.

Major accidents when bunkering LNG are therefore possible and can be of severe nature when triggered by the propagation of the consequences resulting from a myriad of failures within the bunkering operation. These could be easily triggered by abnormalities in the application of procedures or in the technology employed by any of the multiple stakeholders. A chain effect from small abnormalities could trigger the chain of events towards major accidents (see Figure 5.1).

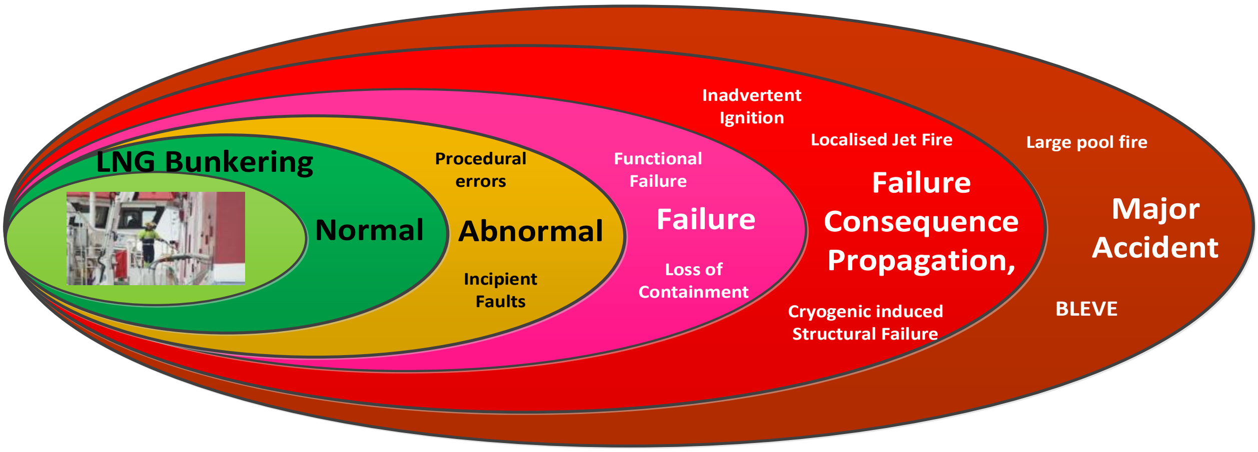


Figure 5.1 LNG Bunkering: From safe operations to potential hazardous conditions. Source: Lloyd's Register, 2019.

The best, well established and most practical way the industry has adopted to minimise accidents and avoid any accident from becoming major in such complex scenarios, is the adoption and application of risk management. This is achieved by implementing risk assessments of the types that are best suited to identify related hazards and come up with ways to minimise the likelihood of its occurrence to a set required level, which is normally mandated by regulatory bodies and administrations.

The risk assessment provides a structured approach for the LNG bunkering providers to identify such hazards and to justify that different risks are reduced to appropriate levels.

The main reason why risk assessments are applied to LNG bunkering operations is that the safety of LNG bulk transport has traditionally relied on IMO legislation i.e. IGC (International Gas Carrier) Code and individual Classification Society rules (e.g. LR Rules for the Carriage of Liquefied Gases in Bulk) and these requirements in isolation could not reflect all possible failure modes that could be the incipient source of accidents; the requirements became reactive in nature, typically based on accidents and failures experienced in the past. Given the relative novelty of LNG bunkering systems and operation, the existing prescriptive rule requirements stand to benefit from complementary risk assessments. Figure 5.2 shows how previous regulations would not cover all that needs to be considered for securing safe LNG bunkering at Ports.

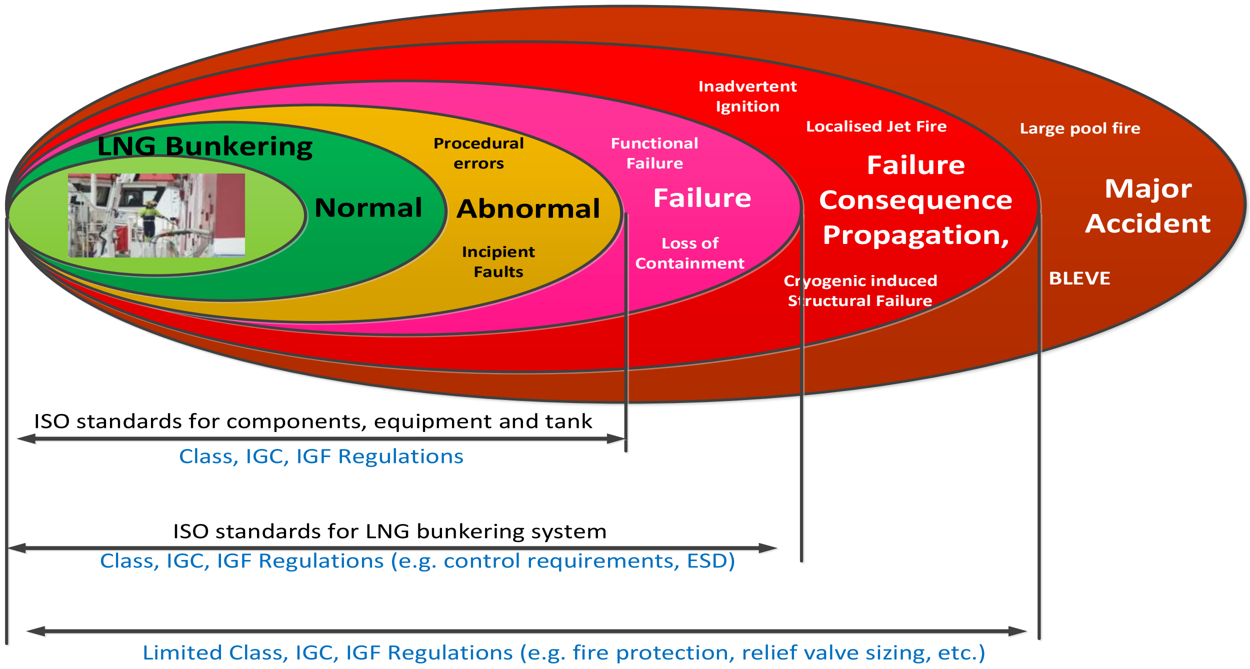


Figure 5.2 How recognised Standards, previous Class Society requirements, IGC and IGF requirements contribute to the safety of LNG bunkering. Source: Lloyd's Register, 2019

The prescriptive requirements in the Lloyd's Register Classification Rules were developed by a panel of experts (e.g. LR's Annual Technical Committee) in response to past LNG accidents and failure experience. Classification rules provide detailed prescriptive requirements for specific types of LNG components, equipment and systems that must be adopted, including functional and performance requirements to be achieved in order for vessels to be classed. Applying these prescriptive rules provides clear instructions on how to design, integrate, construct but also verify and test the different LNG components, equipment and systems. Over the last decade, these requirements have been enhanced by the adoption of risk assessments as the best practice methodology to manage the risks inherent to the relative novelty of LNG bunkering systems and operation. As of today, only by the adoption and application of risk assessments have the Maritime and Port Administrations managed to achieve the safety of LNG bunkering operations at their Ports.

5.1.1. Purpose of Risk Assessments

In general, for any LNG bunkering operation, the intended purpose of the risk assessment is to apply a rigorous examination of the proposed location and operability of the options offered at the LNG terminal/LNG bunkering location site. This in order to demonstrate that all credible accidental events that may happen and could trigger an accident when bunkering LNG, have been considered. The assessment would detail what the recommended appropriate risk mitigation actions for risk reduction are, together with the possible identification of best options for consideration and development by the LNG bunkering operation stakeholders.

To achieve this goal, organizations like Classification Societies and SIGTTO and ISO, envisage the use of formal risk assessment methodologies to ensure that risks arising from the use of LNG as fuel and associated bunkering operations are mitigated to a level of equivalence to that accepted when bunkering conventional fuel oils.

To ensure that risk assessment studies associated with the use of low flash point fuels, like LNG, are undertaken consistently, with an appropriate degree of rigor and in a manner consistent with requirements of Classification Societies, IMO requirements and local Port Administration requirements, the studies should be undertaken according with the following generic four stage process that Lloyd's Register has created and adopted, as shown in Figure 5.3 below, unless stated otherwise in such requirements:

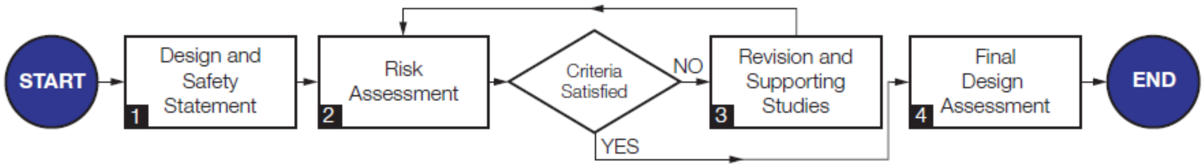


Figure 5.3 Generic process for the assessment of risk-based designs. Source: Lloyd's Register, 2008

5.1.2. Risk ranking methodology

In order to effectively and qualitatively rank risks at early stages of design of the LNG bunkering operation and its impact on Port infrastructure, facilities, equipment etc., an appropriate Risk Assessment Matrix (RAM) could be adopted as shown in figure 5.4 below:

SEVERITY OF CONSEQUENCE

LIKELIHOOD OF OCCURRENCE	5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

RISK EVALUATION

Intolerable

ALARP

Tolerable

Figure 5.4 Risk Assessment Matrix

The orange and green areas of the Risk Assessment Matrix represent the range where the risks are tolerable if they are As Low As Reasonably Practicable (ALARP). This is achieved if the cost of risk reduction would greatly exceed the safety improvements gained. The greater the risk, the greater the disproportion between cost and benefit which is required before an improvement becomes impractical.

The red shaded region represents the range where risks are intolerable and would be required to be reduced by design activities and/or engineering controls.

The risks identified during a Risk Assessment study could be generically classified according to their severity to:

operations (downtime),
impact on personnel on-board ships or at jetty (health/safety),
impact to the environment
and their likelihood of occurrence.

Tables 5.1 and 5.2 below show an established way to describe the consequences of hazards and the risk categorizations for a Port facility undertaken LNG bunkering operations:

Table 5.1 Severity Definition for conducting LNG bunkering operations at Ports

Severity Level	Severity Characterisation	Consequence Category	Consequence Description
1	Very low or none	Downtime (T_D) Health/Safety Environmental	$T_D \leq 1$ h No/Slight injury No/Slight environmental pollution (≤10 ltr liquid chemicals or oil,1 ≤ kg gaseous chemicals)
2	Low or minor	Downtime (T_D) Health/Safety Environmental	1 h < $T_{\leq}$ 6 h Minor injury, short-term absence from work (≤1wk) Minor environmental pollution (10 ltr < liq. Chem/oil ≤ 100 ltr; 1 kg < gas. ≤ 10 kg)
3	Moderate or significant	Downtime (T_D) Health/Safety Environmental	6 h < $T_{D\leq}$ 24 h Major injury, irreversible health damage, permanent (partial) disability, prolonged absence from work (> 1 wk) Local environmental pollution (100 ltr < liq. chem./oil ≤ 500 ltr; 10kg < gas. chem. ≤ 500 kg)
4	High	Downtime (T_D) Health/Safety Environmental	24 h < T_D ≤ 2 wk Single fatality Major environmental pollution (500 ltr < liq. chem./oil ≤ 10.000 ltr. 500 kg < gas. chem. ≤ 10.000kg)
5	Very high or catastrophic	Downtime (T_D) Health/Safety Environmental	$T_{D>}$ extensive time Multiple fatalities Massive environmental pollution (10.000 ltr liq. chem./oil; > 10.000 kg gas. chem.)

And the likelihood of occurrence is generically defined as shown on table below:

Table 5.2 Likelihood of Occurrence

Likelihood (P) Level	Likelihood Characterisation	Likelihood Description
1	Improbable	P < 1x per 100 yrs.
2	Remote	1 x per 20 yrs. < P ≤1 x per 100 yrs.
3	Occasional	1 x per 4 yrs. < P ≤1 x per 20 yrs.
4	Probable	1 x per yrs. < P ≤1 x per 4 yrs.
5	Frequent	P ≥ 1x per yrs.

5.2. Risk Assessment Techniques

5.2.1. Hazard Identification (HAZID)

A hazard can be described as a situation with a potential to cause harm to humans, the ship, environment and business. It might be a physical scenario (e.g. violation of control zones by third-party vehicles), operation that did not follow protocol (e.g. incorrect installation of ESD), different failure modes, among others. The fundamental goal behind the HAZID is to identify the causes of accidents before they occur so they can be eliminated or mitigated in terms of design changes and/or operational response.

For a typical LNG bunkering study, a hazard identification (HAZID) study would be carried out. It is a systematic approach used to identify the hazards, causes and consequences associated with the LNG bunkering operations. The outcomes of the HAZID study are used to recommend design changes, operational changes and additional safeguards as required.

The HAZID workshop requires the attendance of operators and subject matter experts including:

Ship owner and operator,
LNG bunkering provider,
Terminal Representative,
Port Authority,
Harbour Master,
LNG experienced mechanical, electrical and fire/safety engineers,
Local regulatory authority (if, as necessary), and
Local emergency service (if, as necessary)

A HAZID is typically divided into nodes for better focus and analysis:

- **HAZID Node 1:** LNG bunkering and bunkering arrangement, including the tanker truck and ship connections (including the safety systems)
- **HAZID Node 2:** LNG tanker truck entering, positioning on vessel and departing vessel

These nodes are then subjected to a check list of possible hazards to evaluate the resulting consequences and scenarios. The hazards check list which consists of hazard prompts that were developed for an LNG bunkering study is shown on table 5.3. below:

Table 5.3 Possible Hazards considered in a typical LNG bunkering HAZID study. Source: Lloyd's Register March 2021

Category subjected to hazards	Items where hazards would be considered
Equipment Failures	- Mobile hose holding device - Mobile retention tray - Flange spray tray - LNG hose and coupling - Interface: RSO to LBV / LBB / Truck / Pipeline - Tanker Truck - ESD - Quick connect / disconnect coupling
Location / Environment	- Location hazards - Other interfacing activities at location
Materials	- Flammable / oxidizing material - Toxic material - Corrosive material - Inert gases
Operating Parameters exceedances	- Temperature - Pressure - Flow - Level
Abnormal Operating Modes	- Operation of RSO ship power - Moorings
Human Errors	- Human fatigue - Unfamiliar environment / terminology for the bunkering provider personnel.
Ambiguous, incorrect procedures	- Procedures for LNG bunkering

5.2.2. Hazard Operability Study (HAZOP)

The HAZOP is a systematic, detailed review of the bunkering that seeks to identify the causes and consequences of deviations from the bunkering system design intent and ideal (exemplar) bunkering operations. In the context of LNG bunkering approvals, the HAZOP is conducted following a HAZID and the final (agreed) bunkering system design between the receiving vessel and the bunker facility (truck, barge/ship, onshore tank).

A HAZOP requires several subject matters experts' persons from different backgrounds such as mechanical, electrical, fire and safety that are considered knowledgeable and experienced with the components, equipment, software and operation of the bunkering system.

A HAZOP will include the following activities:

- Undertake a general examination of the LNG bunkering system during transfer operations, using a typical flow diagram, control diagram, cause-effect charts.
- Assess the consequences of typical upset conditions including flow, temperature and pressure, and identify potential hazards relevant to the operations.
- Provide the basis for developing bunkering operational procedures including emergency response.

Typical HAZOP parameters and deviations used in LNG bunkering studies are shown in table 5.4. below:

Table 5.4 Typical LNG bunkering HAZOP Parameters and its deviations. Source: Lloyd's Register, March 2021

Typical HAZOP Parameter	Deviations considered in HAZOP study
Flow	- No More of - No Less of - No Reverse
Pressure	- High - Low
Temperature	- High - Low
Level	- High - Low
Composition	- Change In
Operation	- Missing steps of operation - Incorrect execution of steps
Other than above	- Specific issues

5.2.3. Failure Mode and Effects Consequence Analysis (FMECA)

The FMEA (Failure Mode and Effect Analysis) / FMECA identifies potential hazards associated with a component, equipment (e.g. Quick Connect Disconnect Coupling QCDC, Powered Emergency Release Coupling PERC, etc.) by breaking down and systematically analysing each failure mode in isolation.

Compared to a HAZID, an FMEA/FMECA cannot evaluate concurrent failures given its scrutiny of each failure mode, replaceable part, elementary function in detail.

However, FMEA/FMECA has an advantage in risk estimation given specificity of the failure consequence and its occurrence.

5.2.4. Quantitative Risk Analysis (QRA)

EMSA defines a QRA as “a well-known and widely accepted methodology to quantify safety risks. It is an approach to determine risk levels associated with accidental Loss of Containment events (e.g. LNG spills, large gas releases)”. In reality, while there is growing maturity in the development and acceptance of QRA in the Marine and Offshore industries, there remains specific challenges in using a QRA to analyse and justify the safety of LNG bunkering operation.

Applying QRA to LNG bunkering operations to quantify the risks from hazardous events such as loss of LNG containment LOC (large spill event), fire events, etc., involves a thorough consequence analysis associated with the hazard and the quantification of the frequency at which different faults and failures are expected to materialise. The resulting risk is then analysed against recognised risk criteria in finalising the LNG bunkering design and operation. Getting reliable statistics of failure of components, mechanical, electrical, control software failures and of human errors is challenging for what is currently still considered a novel operation in maritime, therefore, a number of assumptions will have to be made in order to populate the statistics and carry out the QRA study meaningfully.

5.2.5. Manoeuvring Simulation Study

Although not being a risk assessment technique, it is recommended to do studies to assess the feasibility of the approach of the LBV / LBB to the terminal berth / bunkering location at Port where the RSO is berthed, and identify any marine traffic management requirements. This will assist with reaching an understanding of the risks associated with all vessel movements within Port, and interaction with terminal lay-out, under a range of environmental / weather scenarios likely to be encountered at the bunkering operation location/s. This study could be required in order to address an action to be dealt with from a HAZID.

5.3. Risk Assessment applicable to LNG bunkering operations at Ports

Specifically, when applying risk assessment to the safe operation of LNG bunkering at Ports, the following objectives are in general expected to be addressed by the assessment, as best practice, in order to evaluate the Port's ability to comply with safe LNG bunkering requirements:

Undertake a site survey of the available options in order to carry out safe LNG bunkering operations at that site and to improve the understanding of the actual area positioning and especially their proximity to main Port facilities (i.e. cranes, fixed installations, servicing areas, etc.).
Undertake a detailed examination of maritime operations and identify potential issues associated with the LNG bunkering vessel / barge / LNG Carrier supplier ship and their approach and berthing operations at the proposed site/s.
Establish the navigation critical scenarios required to be verified by real time manoeuvring simulations in compliance with IMO, Classification Society and SIGTTO recommendations.
Undertake a qualitative evaluation of each proposed site and identify potential advantages and drawbacks which may have an impact on the technical, operational or commercial long-term viability when performing LNG bunkering within the required levels of safety.
Establish critical requirements with regards to the adequacy of the proposed LNG bunkering operations and specific Port Procedures in line with similar international Port operations in order to ensuring the long-term integrity of the bunkering operations.
Perform a round table discussion of potential maritime failure mode scenarios and emergency response procedures in order to further reduce any potential hazards and minimise risks.

In today's maritime industry, safe LNG bunkering operations require the undertaken of risk assessments to the satisfaction of certifying authorities and with regulator approval. All four techniques described in section 5.2 could be adopted, included the Manoeuvring study when required from a HAZID. These techniques as such are not mandatory, however, they are the ones widely adopted by the industry globally, due to a combination of their proven adequacy to meet requirements, increased global familiarity with its proper application and effectiveness in addressing the safe operation of LNG bunkering. It is however possible that new novel techniques could also be accepted in lieu of these ones if the certifying bodies agree to use them after having found them able to deliver an equivalent level of trusted evidence to the four well-established ones.

The following table shows what risk assessment are expected to be undertaken for each of the most common LNG bunkering transfer operations and the rationale behind it. The [B2 C 2.5] details the content and structure of the documents that the BFO should submit in order to perform LNG bunkering operations and [B2 C 3.2] gives a set of recommendation to the PA in order to evaluate the analysis.

Table 5.5 Risk Assessments and their applicability to the LNG Bunkering Operation at Ports

Risk Assessments and their applicability to the LNG Bunkering Operation at Ports			
Bunkering Operation	**Minimum Risk Assessment Requirements**	**Additional Risk Assessment Technique(s)**	**Rationale for Risk Assessment**
Truck to Ship (TTS)	QualRAs (HAZID,HAZOP)		Compliance with ISO 20519, 18683 and Classification Society's Rules
		FMEA, FMECA	Novel bunkering component (i.e. no existing standards, rules) Components with poor reliability Single point of failure, resulting in LNG leakage
		Quantitative Risk Assessment (QRA)	SIMOPs MTTS Risk-based rationalisation, reducing the deterministic safety zone
Ship to Ship (STS) & **Terminal to Ship (PTS)**	QualRAs (HAZID,HAZOP)		Compliance with ISO 20519, 18683 and Classification Society's Rules
		FMEA, FMECA	Novel bunkering component (i.e. no existing standards, rules)
			Components with poor reliability
			Single point of failure, resulting in LNG leakage
		Quantitative Risk Assessment (QRA)	SIMOPs Risk-based rationalisation, reducing the deterministic safety zone
		Bow-tie Analysis (Fault Tree and Consequence Tree Analyses)	Seveso III Directive, Upper Tier Compliance when required Harmonisation of emergency response for high consequence LNG leakages (e.g. ignition of large LNG releases)

As mentioned on section 5.1, there are still not enough prescriptive requirements to cover for all potential causes of major accidents when performing LNG bunkering and is reason why all aspects of such an operation is subject to risk assessments to include as minimum, the implementation of a HAZID and a HAZOP.

Therefore, Port Facilities where LNG bunkering is planned to be undertaken, as well as the LNG bunkering operation itself, no matter what the chosen transfer method, is subject to HAZID and HAZOP studies as a minimum. The IGF code, classification rules and industry associations such as the Society for Gas as a Marine Fuel (SGMF) require the application of a hazard identification study (HAZID) and hazards and operability study (HAZOP) for all types of LNG bunkering transfer operations.

Typically, Bunkering Fuel Operators (BFOs) should undertake Risk Assessment for STS and TTS bunkering operations. Hazard Identification (HAZIDs) and Hazard Operability (HAZOPs) should be conducted as per ISO/TS 18683 and also Section 8.3.3.3 of EMSA Guide and include the closure of all recommendations or a plan for their implementation in the LNG Bunkering Management Plan before the launch of the bunkering operation. In addition, the obligations of ISO/IS 20519 Section 6.3 are to be complied with as a minimum.

The scope of hazard identification normally includes the following as a minimum:

- Undertake a site survey and address feasible types of bunkering operations appropriate for the RVs fuel capacity requirements and their quay berths within Port, rate each option on merits and drawbacks. Establish preferable bunkering methods in the LOI (Letter of Intent) and requirements of the PA before issuing it to the PA.
- Establish size and number of LNG bunkering barges (LBB) and/or bunkering trucks (LBT) capability for re- loading LNG cargo locally or at remote location, turnaround time service requirements and identify short- and long-term impact on port operations.
- Undertake a HAZID review. Identify hazards related to the LBB or LBT bunkering system and their impact on maritime operations, quay or terminal operations, port support operations and emergency response.
- Identify impact of LNG bunkering on any other simultaneous operations (SIMOPS) taking place on quay/terminal or onboard adjacent RV's.
- Undertake a HAZOP review on the LNG bunkering transfer system. Identify hazards related to the LBB or LBT bunkering system connection, fuel transfer and disconnection operations and assess their impact on the RV fuel system, isolation/relief systems, drainage systems and safety controls.
- Identify means of hazard mitigation by introducing appropriate systems like fire and gas detection, active (firefighting) and passive (cryogenic insulation) systems.
- Identify means of hazard mitigation by introducing appropriate Bunkering Operating Procedures.
- Identify supporting systems that are not onboard the LBB or LBT and need to be provided by the PA. These may include but not limited to:
- Firefighting tugs or fire engines
- Mobile firefighting equipment on the quay
- Parking facility for trucks
- Security traffic barriers in association with Security Zones
- Bunkering system equipment, hoses, other consumables on the quay

HAZID and HAZOP reviews to be undertaken in the form of Workshops with the participation of competent representatives from all stakeholders (PA, BFO, RSO, terminal representative and rest of port community involved) under the direction of a study facilitator.

A Failure Mode Effects and Criticality Analysis (FMECA) is performed as part of the safety and reliability analysis of LNG bunkering components. The technique is very effective in breaking down a complex assembly (e.g. emergency release system) and abstract processes (e.g. LNG bunkering control and monitoring software) into distinct replaceable parts and elementary functions. Some of the reasons for requiring an FMEA/ FMECA in the LNG bunkering licencing process will include:

-The use of proprietary components and equipment in the LNG bunkering system. Meaning the component/equipment is relatively new and that there are no existing engineering standards, nor regulations covering its design, development, testing and use.

-Components and equipment with poor reliability figures and/or acting as a single point of failure resulting in LNG release (loss of LNG containment).

An FMEA, FMECA should be required by the Port Authority for LNG components, equipment that are of novel design and present a single point of failure (i.e. no redundancy) in the LNG system. Novel in this context means that the component or equipment is not certified or in the process of being certified by an IACS Classification Society including other independent, recognised bodies (e.g. TUV, Underwriter Laboratories, etc.).

A quantitative risk assessment QRA is performed to find severe fault-failure propagation and their consequences (e.g. simultaneous loading/unloading of passengers during LNG bunkering considering leakage and its inadvertent ignition). The resulting analyses and the quantification of the risk (results of QRA) provide granular, detailed results to support decision-making in the mitigation and/or elimination of the risks. According to ISO 18683, a QRA is required as part of a SIMOPs simultaneous operations given that LNG bunkering conducted in parallel with other vessel operations, divides the attention of the crew and depending on the activities (e.g. cargo loading, repair work, passenger disembarkation, etc.) the consequences for errors and failures can be severe. Given that a QRA is a quantitative, rigorous, systematic tools it will involve:

Multidisciplinary information integration e.g. quantifying the effects of the human errors using Human Reliability Analysis (HRA) with the equipment failures.

Allows consideration of complex interactions. This means it can consider the concurrency of different faults and failures and how they can eventually result in the high consequence accident.

Develops quantitative measures for decision making, including a structure to develop sensitivity studies.

A “bow-tie analysis” meaning a combined fault tree leading to the failure event then its consequential propagation to further failures (consequence tree) can be a regulatory requirement if the LNG bunkering operations meets the “upper tier” criteria of the Seveso III regulations.

Since Seveso III regulations deal with the prevention of large, high consequence accidents concerning hazardous liquids such as LNG, the information produced with classical hazard analysis methods such as HAZID, HAZOP, FMECA are generally not sufficient as major accident scenario documentation. Meaning the HAZID, HAZOP, FMECA are very effective in identifying and evaluating individual failure scenarios and most often they don’t give a clear view on the sequential (logical and temporal) aspects of the development of a major LNG accident scenario. As these techniques search for all potential faults and failures, they are also very detailed and therefore tend to be difficult to read for someone who has not been involved in the study. In contrast a bow-tie model presents an accident scenario in a way that makes it easy to understand and to evaluate it, even for someone who didn’t participate in preparing the different analyses. This will be very useful in preparing, coordinating and harmonising multiple emergency responses such as those expected from the LNG bunkering provider, receiving vessel crew, port emergency services, all the way to local and national emergency units.

5.4. LNG bunkering control zones

Controlled zones are areas extending from the bunkering manifolds on the LNG receiving vessel and the LNG supply source during LNG bunkering operations that have restrictions in place. These restrictions include limitation on personnel access, sources of ignition and unauthorized activities.

The controlled zones are subdivided into:

- Hazardous Zones,
- Safety Zones,
- Monitoring and Security Zone

As per ISO/TS 18683 and ISO 20519 definition,

EMSA Guide as well as SGMF FP02-01 Recommendations of Controlled Zones during LNG Bunkering, version 1.0, May 2018 also considers a “Marine Zone or Marine Exclusion Zone”.

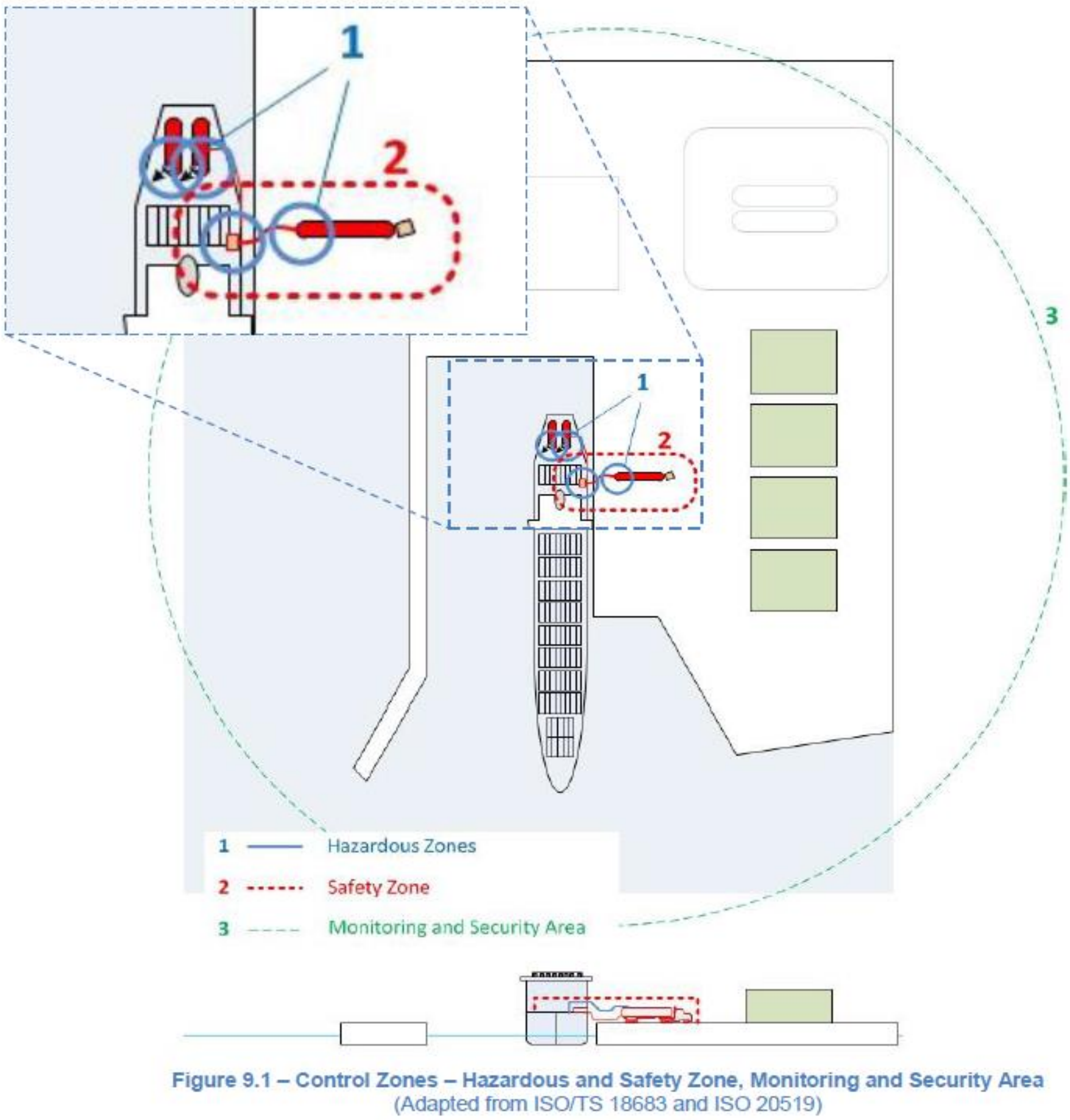


Figure 5.5. Representation of LNG bunkering control zones. Source: EMSA, January 2018.

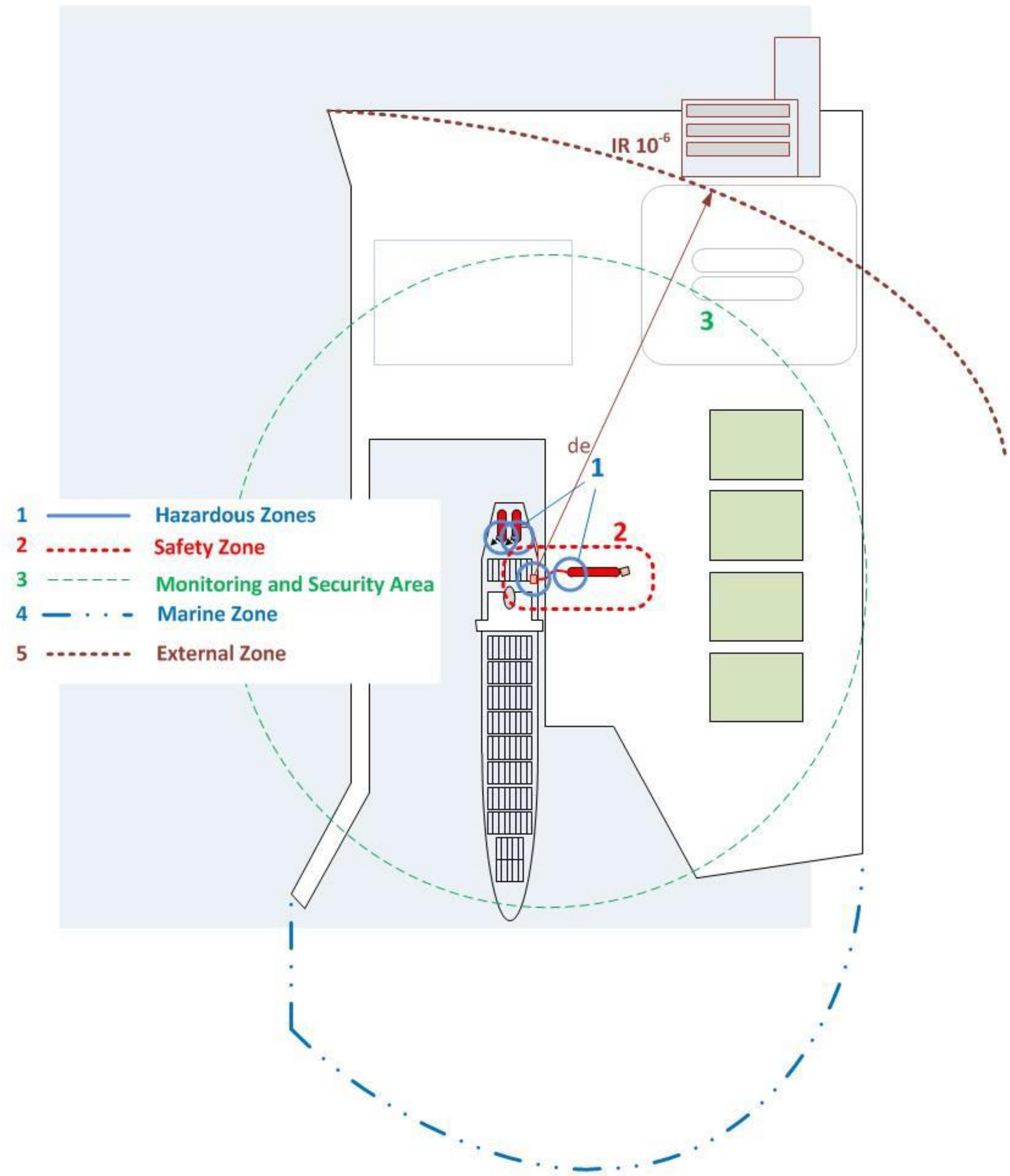


Figure 5.6. Representation of LNG Bunkering control zones, including EMSA and SGMF guide recommendation. Source: EMSA, January 2018.

5.4.1. Hazardous (Area) Zone

Definition of Hazardous (Area) Zone - an area in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of personnel and asset. These special precautions refer to the requirements for the construction, installation and use of components and equipment described in BS EN 60079 -10-1. Hazardous Zones are present at all times and are not operation dependent.

The initial location (siting) analysis of an LNG bunker facility including its staging, waiting position (i.e. LNG bunker barge berthing and LNG bunker truck parking) should be determined based on the safety of the general public, Port personnel and surrounding Port infrastructure against known LNG hazards. These hazards include LNG release resulting in cryogenic hazards, asphyxiation, vapour cloud formation and its inadvertent ignition leading to fire. Conversely, there are Port hazards such as passing ships, car traffic, industrial activities that can adversely affect the safety of an LNG bunkering operation.

The most common form of hazard prevention is to define and designate an exclusive area for the LNG bunker facility. This means carrying out a hazardous zone analysis to limit and specify the type of equipment (i.e. controlling and eliminating ignition sources) that can be used and a safety zone analysis to exclude port activities, ingress of public and limit access to professional LNG bunkering personnel for the duration of the bunkering operation.

The hazardous zone analysis is the first one that must be undertaken in order to determine a location/s where it is considered that LNG bunkering operations could be made safe within the Port, a location where intrinsic LNG leakages are expected, that is leakages inherent with LNG transfer systems and technology that are unavoidable, therefore, need to remain within the hazardous zone, where the necessary precautions to limit the creation of sparks are imposed. Such locations must meet the criteria set by the analysis or else a safety zone cannot be determined.

During site planning, sufficient distances as per hazardous area matrix and safety zone matrix should be considered, positioning the tank, LNG equipment, components away from the following:

Leisure and public facilities such as passenger terminals and promenades
Port buildings and infrastructure, particularly those that are occupied during planned bunkering hours.
Fixed ignition sources such as cranes, refrigerated containers and other industrial facilities
Storage of other dangerous substances (flammable, toxic substances as per IMDG code)
Port boundary, particularly if it is adjacent to a public road or public infrastructure that are normally occupied during bunkering.

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5.4.2. Safety Zone

Definition of Safety Zone - an area that is defined and enforced during LNG bunkering operations within which only essential personnel are allowed and potential ignition sources are controlled. The extent of the safety zone can be defined by the worst credible leakage analysis or alternatively via quantitative risk assessment.

A Safety Zone is a three-dimensional area around an LNG bunkering operation, which is created from the accidental leak or emergency discharge of LNG or vapour, only during bunkering operations. This zone is temporary in nature and is only present during bunkering. In this area, only dedicated and essential personnel and activities are allowed during bunkering.

The needs for implementing Safety Zones are:

- To control ignition sources in order to reduce the likelihood of igniting a flammable gas cloud that has dispersed following an accidental release of LNG or natural gas during bunkering.
- To limit the exposure to non-essential personnel in the event of potential hazardous effects (e.g. fire) during an accident when bunkering.

- To assess local infrastructure for any potential gas trapping points, where explosive atmospheres may occur, because of accidental gas cloud dispersion.

BFO should identify the extend of Safety Zone under the scope of the Risk Assessment work for bunkering operations. The scope of Risk Assessment for the determination of the Safety Zones would typically include the following as a minimum:

- To include a clear methodology as per ISO/TS 18683 and ISO 20519.
- To consider the standard hydrocarbon industry approach of using Consequence Analysis techniques to calculate the flammable extent of an LNG release. The safety exclusion zone will be determined based on the extent of the flammable gas plume; this approach should provide a conservative estimate of the zone's extent.
- The study should include modelling and LNG dispersion simulations for an adequate range of release sizes, to represent credible LNG release scenarios originating from potential points of release from the bunkering system on LBB or LBT and the receiving vessel.

The study can follow either:

- **Deterministic approach** calculating the distance to LFL based on a maximum credible release. For LNG, the LFL is approximately 5% of gas in air. Computational calculations should be undertaken typically by less computer consuming tools like the 'Integral Models' presented in EMSA Guidelines (Ref. table 9.1.1). The approach does not take the probability of event occurring into account. This approach is recommended for STS bunkering operations involving LBB and TTS operation involving a single truck.
- **Risk based** approach based on QRA methodology. This approach takes the probability of event occurring into account. This approach is recommended for more complex bunkering operations involving TTS using multiple connected trucks and PTS using quay pipeline bunkering from a storage facility.
  - All release scenarios should be clear and relevant to the bunkering operation.
  - All assumed operating parameters should be clearly presented.
  - Conclusions and results should be clearly presented. Guidance could be sought from the following standards and guidance:
  - ISO18683,
  - ISO16901:2015(en), Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface,
  - ISO11231:2010(en), which describes the Probabilistic Risk Assessment, that is applied to Space Systems, and could also be extrapolated to QRAs for Gas systems, as a guidance reference,
  - IACS Rec.142,
  - EMSA Guidance, sections 8.2.3., 8.3 and 8.6.

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Safety Zones cannot be smaller than Hazardous Area Zones determined by design.

Safety Zones should always encompass the bunkering manifold connections of both LBB barge or LBT and the RSO bunkering terminal. In the case of MTTS bunkering, all truck connections and the common pipeline connection to the RSO's manifold should be included within the Safety Zone.

The following restrictions will typically apply within the Safety Zone:

Smoking is not permitted.
Naked lights, mobile phones, cameras and other non-safe certified portable electrical equipment are strictly prohibited.
Cranes and other lifting appliances not essential to the bunkering operation are not to be operated.
No vehicle (except the LBT) should be present in the safety zone.
No ship or craft should normally enter the safety zone, except if duly authorised by the PA.
Other possible sources of ignition should be eliminated.
Access to the safety zone is restricted to the authorised staff, provided they are fitted-out with personal protective equipment (PPE) with anti-static properties and a portable gas detector.
Ventilation Intakes in the entire safety zone should be restricted, with tag-out policy applied whenever LNG bunkering is underway.

In practice, Safety Zones from STS bunkering operations have an impact on ship passing traffic and no impact on Port's quay operations.

In practice, Safety Zones from TTS and PTS bunkering operations have an impact on Port's quay operations and no impact on Port's ship passing traffic.

The PA should oversee the typical elements required to enforce a Safety Zone including but not limited to the following:

Physical barriers
Visual road signs or notices
Portable road lighting

5.4.3. Security Zone

Definition of Security Zone – closely follows the safety zone required during LNG Bunkering, for the purpose of establishing a wider perimeter in order to control access, road traffic and other port activities in the vicinity of the LNG bunkering operation when safety zone is extended beyond the RV.

In general, the Safety Zone for each specific location and bunkering mode determines the Security Zone, as it must be larger than the Safety Zone. The security zone is the area around the LNG transfer equipment that needs to be monitored as a precautionary measure to prevent interference with the LNG transfer during operation.

5.4.4. Marine Zone / Marine Exclusion Zone

This zone is established to minimize risk from passing through ships whilst an LNG bunkering operation is undertaken. This is done by creating an exclusion passage zone that no ship is allowed to trespass until the LNG bunkering operation is completed safely.

Such a zone may introduce higher disruption in the Port, depending on the physical layout of the Port areas chosen as the LNG bunkering zone. The main aim of the Marine Zone would be to protect the RSO and LBB/LBV by preventing marine traffic passages through the Safety Zone while the LNG bunkering operation is active, so that the LNG transfer is not impacted.

The definition of the Marine Exclusion Zone is for each Port to decide and implement in Port rules, based on specific Port and ship studies.

Every Port would need to decide whether to impose the physical Marine Zone, also called Marine Exclusion Zone by SGMF guide, enforced while LNG transfer is active, or opt to adopt other risk managing measures, in case physical passage is considered necessary and the safety zone area interferes greatly with the navigation passage zone. For example, EMSA recommends that when passing through a safety zone is inevitable, there should be procedures in place to make the Safety Zone limits well visible and allow the passing vessel to do so in the safest way possible. Whilst exceptions exist, we would recommend that where LNG bunkering will take place by larger LNG bunker vessels (LBV), transporting bunker from an outside terminal facility or undertaking lightering operations from an anchorage; in this case, BFO should undertake a risk assessment to verify the safety of marine operations.

Any restrictions applied to STS bunkering will be Port specific, reflecting the local conditions, Port layout, Port operational activity and collision accident prevention policy.

Below figure 5.7 illustrates the possible relationship between the Safety Zone and the Marine Zone, or Marine Exclusion Zone as described by SGMF guide.

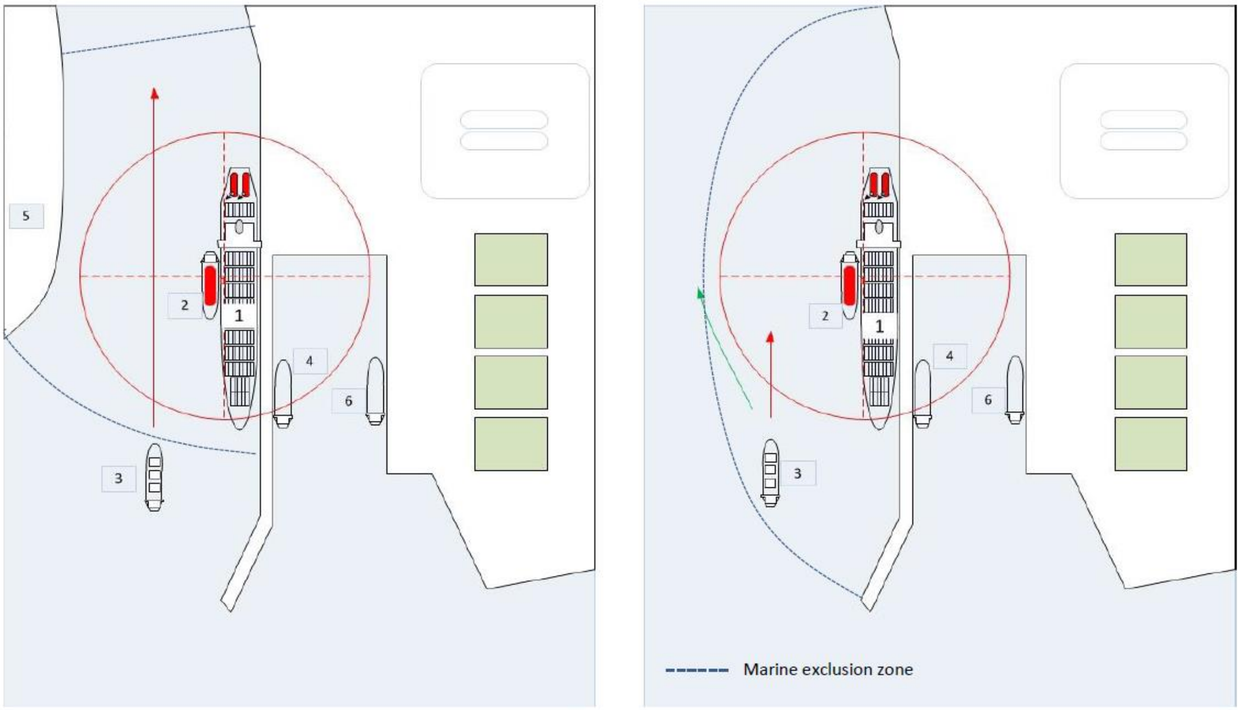

Figure 9.23 (left) and 9.24 (right) – LNG Bunkering Safety Zone implementation – Marine exclusion zones designed to avoid the proximity of the passing by vessel.

Figure 5.7. Representation of LNG bunkering Marine Zone / Marine Exclusion Zone, as shown by EMSA and SGMF guide recommendation. Source: EMSA, January 2018.

It is recommended, as a minimum requirement, that the Marine Zone is set in such a way to avoid any ship's passage through the safety and security zones set around the RVs while LNG bunkering is taking place, as illustrated in Figure 5.7 above.

5.5. Maritime Traffic Risk Assessment

The scope of maritime risk assessment to be undertaken by the BFO should be as follows:

- Include maritime operations and identify any hazards under the scope of the HAZID study.
- Based on any issues identified by the HAZID, undertake a maneuverability analysis in order to:

- Verify the safe passage of bunker LBVs to the port and within the port until they reach the STS serving location(s).
- Verify the safe manoeuvring of the bunker vessel for berthing alongside an RV
- Verify if any tugs may be required for transit and berthing operations.
- Verify the safety of manoeuvring plans and identify emergency response procedures in line with PA's existing requirements.

Issues relating to impact collisions will not be considered as all movement of bunkering barges takes place under low controlled speeds within the benign environment of port waters. The transportation of LNG via LBBs or LBVs outside the port boundaries and issues related to the safety of navigation and avoidance of potential risk of collision/grounding and release of LNG should be addressed by the Competent Authorities as part of the EIA.

5.5.1. Guidance on Ship Manoeuvring Simulation

In order to assess the feasibility of the approach of the LNG Bunkering vessel to the terminal berth and identify any traffic management requirements at the terminal area, either preliminary Manoeuvrability / Manoeuvring Simulations or real time simulations should take place.

To fully understand the risks associated with all vessel movements, and interaction with other shipping terminal lay-out, and navigation aids, real time simulations provide a sound approach. This follows the recommendation on simulated assessment given by SIGTTO in their guidance on terminal and operations/site selection. Therefore, real time simulations will be more applicable when there will be infrastructure inside the Port.

The purpose of a preliminary simulation is not only to determine the initial practicality of the LNGC/Bunkering vessel manoeuvre, but to also run a few manoeuvres on a risk-based approach under adverse weather scenarios in order to assess the operability of the preferred terminal option/berth and any potential impact to safety, commercial operations and the environment. This would enable the project to further enhance the initial feasibility assessment of the terminal/bunkering site and determine appropriately the scope of detailed simulations to study as the project activities progress.

The simulations are conducted using certain ship handling and manoeuvring type approved simulators. For example, REMBRANDT is a Windows based software application designed to run on any laptop or desktop computer of suitable specification that is using a Microsoft operating system. It can be configured in single or multiple screen modes with a variety of user control options.

All simulations should be conducted by a Pilot with experience of a certain number of port entries and departures. The Pilot controls the vessel directly (i.e. without issuing orders) and manoeuvres the tugs using the external function display. The Pilot has the following information available in real-time:

the electronic chart view (ECDIS) showing the position of the vessel on the chart and other information such as any dredged areas, under keel clearance (UKC), turning circles and exclusion zones;
an out-of-the-window 3D view from the ship's bridge (switched to the bridge wings when required);
run information such as the vessel speed over the ground (ahead/astern and lateral), rate of turn, heading and course over the ground. Also, depth profile and engine/rudder values (actual and demanded);
position and percentage of power usage for each tug.

The typical run information screen, which is available to the pilot during the simulation is shown in Figure 5.8 below.

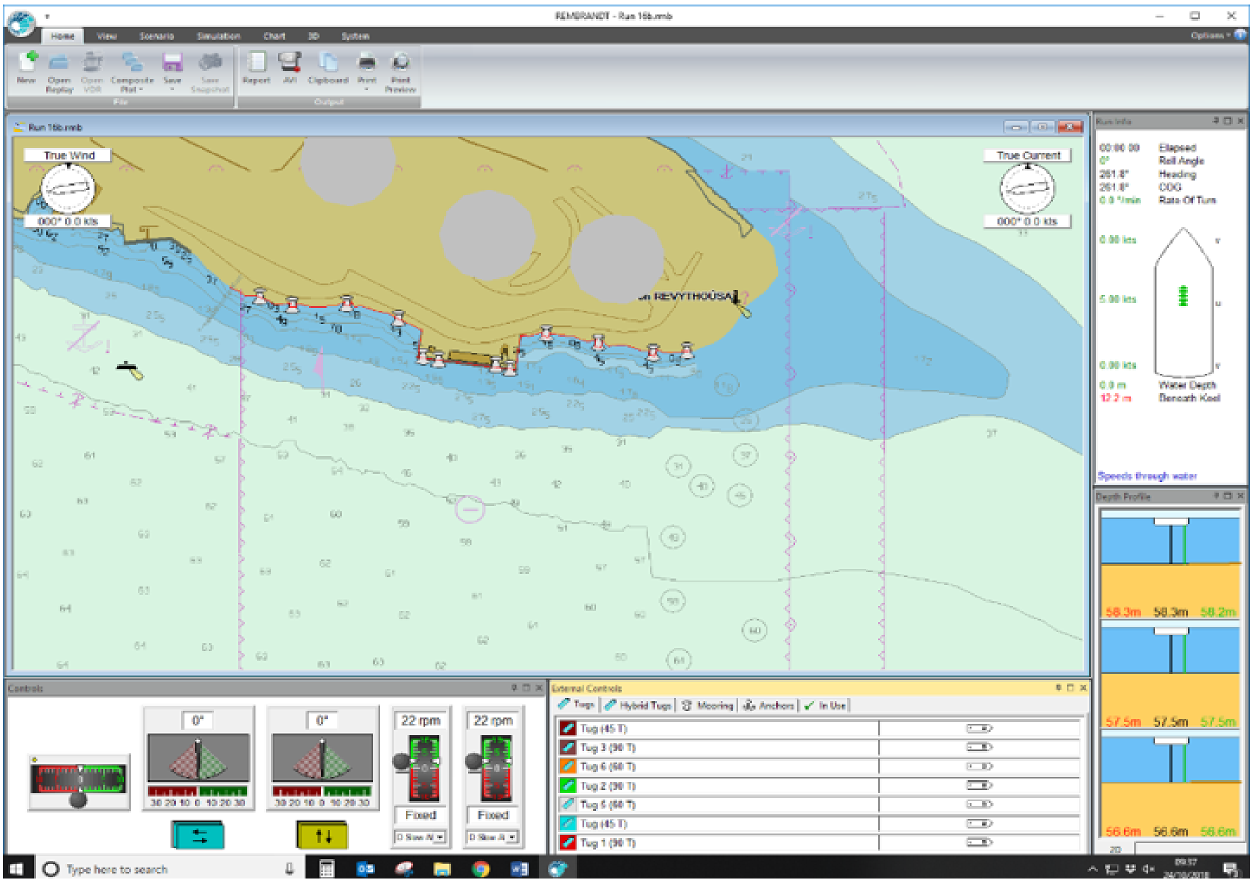

Figure 5.8 Example of a current Navigation Simulator Screen. Source: BMT 2018

Official Hydrographic Office electronic charts are used for the simulations.

Each run is set up with the met-ocean conditions and the ship's initial position, speed and course.

At the end of each run, a run report form is completed, they include a qualitative grading (see Figure 5.9 below) as to the difficulty of performing each manoeuvre as a means of comparison for the study. The contents of each report form and its grading are completed upon the conclusion of each manoeuvre.

Run difficulty up to and including "Not Demanding" is suggested as being standard ship navigation/manoeuvre operation. It is noted that in practice runs rated as "Not Easy" and above, require additional thought and preparation from the team performing them and should not be considered standard port practice.

1	2	3	4	5	6	7	8
Easy	Straight-forward	Comfortable	Not demanding	Not easy	Challenging	Difficult	Impossible

Figure 5.9 Navigation Simulator Grading Matrix

The relevant typical size of shuttle LNG ships/LNG Bunkering vessels represented by a modern design are used for the simulation study.

Wind, wave and current data is based on input from certain databases. Relevant currents are also assumed as appropriate.

Various wind directions are investigated with speeds up to 35 knots used. All runs are carried out with gusting wind. In REMBRANDT, for example, the gust speed is randomly varied by 25% to 31% of the base wind speed. The wind speed is then either increased or decreased (50/50) by the gust speed. Furthermore, the direction is randomly adjusted between -9° and 9°. This occurs every 10 to 25 seconds.

Corresponding wave conditions are used with mean significant heights up to certain meters.

The manoeuvring simulations run the scenarios assuming a specific number of tugs as appropriate.

Digital technologies are currently under development for different aspects of maritime navigation and remote controlling of ships, including first generation synthetic testing laboratories, where in the future, high fidelity simulations could be performed very fast, including multiple scenarios and combination of risks and constraints that have not been possible to achieve previously.

5.6. Road Transport Risk Assessment

For Ports where LNG bunkering will take place by visiting LNG trucks transporting bunker from a terminal facility, the BFO should verify the safety of operations by risk assessment.

The scope of risk assessment to undertaken by the BFO should allow for:

- Verify the safe road transportation of LNG within the specific Port's road access system, by for example, performing a HAZID study.
- Verify the number of LBTs required to complete specific TTS operations and the safe available parking facilities at the proposed quay where TTS will take place.
- Verify that the potential truck operations impact to Simultaneous Operations (SIMOPS) has been addressed.
- Address any issues of LBT traffic risks impacting outside the PAs boundary and communicate these to Competent Authorities for their review and approval.
- Establish appropriate emergency response procedures and communicate these to PAs, for plans to be implemented involving any external emergency support (fire brigade, mobile cranes etc.)
- Ensure that the route of the trucks inside the port shall be decided in compliance with the road traffic rules established by the PA.

Competent Authorities are responsible to verify and accept LNG road transportation risk assessment outside the port's boundaries. BFO's should agree on the approval process and compliance requirements with Competent Authorities during the feasibility stages of the project.

5.7. Simultaneous operations (SIMOPS)

Definition of SIMOPS = Simultaneous Operations: Defined as two or more activities that occur at the same time, one of which involves a LNG Bunkering process, the combination of which may lead to an increased safety risk. Parallel activities include, but are not limited to, disembarkation / boarding of passengers and / or crew, picking up passengers, vehicle loading / unloading, cargo handling, refuelling or lubrication, cleaning / repair work etc. (ISO 20519 definition)

LNG bunkering operations are bunkering operations using a new bunker fuel. As with other forms of bunkering an increasing number of RSOs require that appropriate SIMOPS procedures be put in place to allow the receiving vessel to continue with its normal operations at berth.

It is noted that restrictions for SIMOPS have a strong influence on the commercial RSO's performance and can increase turnaround times at Port. There is therefore a strong driver from the maritime industry to make SIMOPS viable by appropriately identifying and reducing risks using the process of Risk Assessment.

BFOs are responsible to evaluate SIMOPS as part of the risk assessment scope of work, but Terminal Operator should approve it and participate in its elaboration as being responsible for the space where operations take place. The scope of SIMOPS risk assessment to be undertaken by the BFO should be as follows:

- Adopt process from the latest SIMOPS guidelines
    - USCG CG-OES Policy Letter No.01-17- Guidance for Evaluating Simultaneous Operations (SIMOPS) during Liquefied Natural Gas (LNG) Fuel Transfer Operations and
    - LGC NCOE Field Notice 01-2017 – 14-Aug-17 – Recommended Process for Analysing Risk of Simultaneous Operations (SIMOPS) During Liquefied Natural Gas (LNG) Bunkering.
    - [EMSA] Guidelines Chapter 11.
    - SGMF LNG Bunkering Guidelines.
    - IAPH LNG Ready Terminal Guidance.
- Involve input from both RSO regarding the vessel operations at berth and the Terminal Operator regarding the port operations which normally take place on the quay side during these SIMOPS.
- Evaluate the potential impact of the Safety Zones on SIMOPS during LNG bunkering.
- Evaluate the potential impact of SIMOPS on PA's Emergency Response operations.

PA should verify and accept the results of the risk analysis performed and proceed to evaluate any potential issues impacting on the PAs Operational Procedures in order to authorise SIMOPS to take place. A set of recommendations to perform this evaluation are in [B2 C3.2.4].

In addition, for the PA to authorize that SIMOPS can be performed, the PA should ensure that any simultaneous activities that are performed in parallel to LNG bunkering operations in the RSO do conform to the SIMOPS study and a specific and individual report is provided as is detailed in [B2 C 2.8] and [B2 C 3.1.3]. The PA should ensure that conformance with SIMOPS study requirements is routinely verified and that any deviations are identified.

The BFO and the RSO (either the Master (for STS) or the Person in Charge – ISO Standard 20519 – paragraph 6.5.2.1(b) PIC: qualified Person In Charge) shall notify the PA in advance of the intention for SIMOPS.

EMSA recommended procedure is to allow Simultaneous Operations SIMOPS.

It is important for the PA to develop a structure approach to allow for SIMOPS when risk assessment studies have been undertaken and also incorporate methods to address any future deviation. The approach described in Table 5.6 has been adopted by EMSA Guidelines and had been successfully implemented at some Ports already.

Table 5.6 Port Authorities Guidance approach to allow SIMOPS. Source: Lloyd's Register 2019

Activity	Who	Action
Request for SIMOPS	PIC	Person-in-Charge (PIC) requests SIMOPS in advance of bunkering operations The PIC is responsible to ensure that all information sent is consistent with the existing approved Risk Assessment addressing (among others) SIMOPS. Request should describe with detail what type of SIMOPS is/are intended. Request should also identify all stakeholders involved, with relevant contacts for all operators.
Evaluate SIMOPS Request	PA	SIMOPS request is evaluated – Consistency between request and existing information on Risk Assessment is verified. Evaluation of the overall operational scenario in the Port Area.
Call for SIMOPS Preparatory meeting	PA	With the information from SIMOPS request, the PA initiates SIMOPS Preparatory Meeting. RSO, BFO, PA, Other Operators should be present at the meeting to discuss possible operational aspects that should be addressed in advance.
SIMOPS Preparatory meeting	PA BFO RSO-PIC	For SIMOPS in the Safety Zone, should any differences be noted between assumptions. Only existing approved Risk Assessment elements should be considered. The SIMOPS Preparatory meeting is not intended to be a substitute for a HAZID or an informal risk assessment.
Verification Implementation of Risk Mitigation Measures	PA BFO RSO-PIC	Implementation of Risk Mitigation Measures. Protection Measures and Safeguards should reflect the existing Risk Assessment.
Authorization	PA	Authorization for SIMOPS to be used upon positive confirmation that all agreed safeguards and protective measures have been implemented.

6. Emergency Response

6.1. Emergency Response Planning at Ports

Emergency response planning should include provisions to ensure that local authorities and emergency services are aware of the potential risks associated with LNG bunkering.

ISO/TS 18683:2015 should be followed and a Contingency Plan shall be in place by the PA.

The role and responsibility of the respective personnel should be clearly stated.

Practice drills shall be carried out at regular intervals – at least twice a year – with the participation of all personnel involved.

Relevant personnel should have undergone training in fighting gas fires, treatment of cryogenic burns etc.

It is recommenced that a Port Emergency Response Manual is in place, to address the following as minimum requirements for the BFO and RSO:

- Emergency Situations
- Emergency Response Procedures
- Emergency Readiness
- Safety Drills
- Emergency Signals

6.1.1. Emergency Situations

It is difficult to anticipate every emergency which could arise and provide precise emergency response actions. However, as LNG fuel propulsion and LNG bunkering systems are considered relatively novel technologies risk assessments should be used as a tool to identify and document the hazard consequences requiring emergency response which may not be covered by the ships existing emergency response plans.

The following situations are some typical events where appropriate emergency procedures should apply:

- Loss of manoeuvrability/power during berthing: Emergency response actions should be taken while the situation is still under control and avoid potential traffic impact on the port operations. Port Authority (Harbour Master) should be kept directly informed. Typically, response actions may involve request for additional tug support at the location.

- Vessel impact collision: Emergency response actions should be taken by ship's Master normally covered by existing plans. It is expected that response actions should be updated to address potential LNG fuel leakage. All bunkering operations should be immediately suspended. Port Authority (Harbour Master) should be kept directly informed.

- LNG and / or vapour release during operations: Emergency response actions should be taken by PIC to initiate ESD I with bunkering operations stopped and fire response teams deployed. Depending on the extent of the event, ESD II with bunkering system disconnection and emergency release of mooring lines may be initiated.

- Mooring line(s) breakage: Emergency response actions should be taken by Mooring Master to rectify situation. Bunkering operations to be suspended but system remains connected unless due to exceeding arm/hose operating envelope ESD II and disconnection are initiated.

- Extreme weather conditions: Emergency response actions should be taken by ship's Master with all bunkering operations immediately suspended. If at anchorage actions may include emergency unmooring for ships to be able to take refuge at nearest port. Port Authority (Harbour Master) should be kept directly informed.

- Blackout: Emergency response actions should be taken by the ship's Master with all bunkering operations stopped. Emergency response during blackout is normally covered by existing plans but these need to be updated to address bunkering system safe recovery.
- Vapour relief as a result of LNG tank overpressure: Emergency response actions should be taken by PIC to immediately reduce transfer flow or initiate ESDI with bunkering operations stopped. Areas should continue to be monitored for flammable gas and actions should eliminate any potential of ignition.

The examples above are typical of potential emergency situations but do not necessary include all response actions and Masters with the PIC should ensure all contingencies are carefully evaluated. For example, they may need to consider, in the case of fire, whether it is of mutual benefit for the ships to remain alongside or to separate. In this respect contingency plans covering the possible range of emergency scenarios should be considered as part of the ships safety management system.

After an event of LNG leakage, operations should only resume with previous permission of the PA and the agreement of both Masters once the spilled LNG has been safely drained/vaporised and any vapour associated with the leak has dispersed and safe atmospheric conditions have been verified. Due account should be given to any hazardous/cryogenic properties of the LNG or vapour released and the potential impact to responding personnel and unprotected steel structure on deck.

6.1.2. Emergency Response Procedures

Vessels involved in bunkering operations must develop emergency response procedures, which will be an integral part of their Safety Management System (SMS) in compliance with Port Authority requirements.

The emergency response should include a contingency plan which should set out the responsibilities, roles and actions of all parties involved in the operations and the non-bunkering periods making maximum use of their available resources (expertise, equipment etc.).

In an emergency, both Masters and PIC should assess the situation and act accordingly within this pre-determined plan. The following typical actions should be taken in the event of an emergency arising during bunkering operations:

Stop the fuel transfer.
Sound the emergency signal.
Inform the crews on both vessels of the emergency.
Manning the emergency stations.
Implement the prepared STS emergency procedures.
Drain and disconnect the bunker hoses if there is enough time, otherwise, use the emergency release system.
Crew to standby at their mooring stations.
Inform Port Authority of the emergency and request tug support if applicable.
Initiate fire-fighting response.
Initiate anti-flooding response (bilge and ballast systems) if necessary.

With reference to the above actions Emergency Response Procedures should be prepared and their effectiveness critically verified. Emergency Response Procedures shall contain but not be limited to the following:

Contact details of PIC and person(s) in charge of operations.
Contact details of key operating, safety and security personnel.
Procedures for raising the alarm.

Cessation of operations during emergencies.
Mustering of passenger and personnel to designated safe areas.
Emergency stations and preparations to initiate emergency procedures.
Procedures for evacuation.
Deployment of response teams to mooring stations.
Emergency disconnection of bunkering system.
Preparation of propulsion system for immediate manoeuvre.
Procedures for accessing and operation of fire-fighting systems.
Emergency unmooring.
Procedures of handling personnel injuries.

The procedures should be familiar to the personnel involved, who should clearly understand the action they would be required to take when responding to the emergency. Bunkering service providers should have anticipated and fully considered the implication of all types of emergency that might be encountered during an LNG STS bunkering operation. It should be noted that Port Authorities or Coastal Authorities (Coast Guard) may impose specific contingency and notification requirements.

6.1.3. Emergency Readiness

The following arrangements are amongst those that should be made on ships involved in LNG bunkering, both RVs and LBVs/LBBs:

Main engines and steering gear ready for immediate use
All equipment trips relevant to the LNG bunkering system tested prior to the operation
Crew available and systems prepared to drain and disconnect arm/hoses at short notice
LNG spill protection system deployed (water spray)
Mooring equipment ready for immediate use and extra mooring lines ready at mooring stations as replacements in case of breakage
Fire-fighting equipment ready for immediate use
Stand-by tug within safety zone or at position

6.1.4. Safety Drills

It is noted that effective mitigation of an emergency is achieved by preparing ships crews through a system of drills to deal with a variety of emergencies. Drills also provide feedback on the effectiveness of the Emergency Response procedures in place and enable more effective implementation and updating.

An emergency drill should be held, within 24 hours and in any case not more than seven days, preceding a bunkering operation. The times and dates including the crew’s proficiency in the drills are to be recorded in both RSO receiving ship and LNG bunker vessel or barge. Emergency procedures should be prepared, and their effectiveness reviewed during drills.

Emergency response exercise involving the port authorities, bunker supplier & receiver is to be performed (for example annually) once the BFO has been established. This should form part of the review process of the emergency & operating procedures to ensure implementation effectiveness for safe operations. Conclusions from such an exercise should be incorporated within the management of change process.

6.1.5. Emergency Signal

The alarm signal to be used in an event of an emergency on either ship should be clearly understood by the personnel on both ships. An emergency on either ship should be indicated immediately by sounding the ships internal alarm signal and by sounding one or more blasts on the ships whistle, each blast being not less than 10 seconds duration, to warn the other ship. All personnel should then proceed as indicated by the contingency plan. It is emphasised that ships engaged in LNG bunkering operation should be always in an advanced state of readiness to be in a position to deal with emergencies.

6.2. Port Emergency Response Manual

PA shall include in its Emergency Response Manual or “Plan de Autoprotección” the following:

a) A communication protocol with the BFO and RSO which addresses emergency communications during bunkering operations. It is expected that a communications protocol typically exists as part of port’s Operating Manual and this should be reviewed and updated as necessary to include emergency contact:

- By Vessel Traffic systems (VTS) at a specific VHF channel (TBI by the PA)
- Or dialing VTS by phone number (TBI by the PA)

If dialing directly to the national emergency number, VTS shall be informed as well.

The following information should be included in the emergency call:

1. The name of the ship.
2. What has happened.
3. Where has it happened.
4. The number of persons injured and the nature of the injuries.
5. The type of assistance required.
6. Emergency response procedures to be taken in case of fire or emergency on board during LNG transfer, as a minimum.
7. Make an emergency call immediately.
8. Cease all cargo/bunker operations.
9. Start firefighting measures.
10. Disconnect loading arms/bunker connections.
11. Stand by for unberthing.

b) BFO must perform a Consequences analysis study (EAC) according to article 2.3.2 of the RD 1196/2003 in order to zoning the area in case of emergency and help to define the strategies that will shape the Emergency Plan.

c) Emergency response procedures to be taken in case of fire or emergency at the port terminal or adjacent facility to bunkering area as follows:

- Make an emergency call
- Stand by to cease all cargo/bunker operations
- Wait for additional instruction from port authorities or VTS
- Stand by for unberthing

d) A Contingency Plan, for PA Emergency Response planning, according to ISO/TS 18683:2015, outlining the requirements for the following:

- Evacuation of personnel and third parties;
- Mobilizing fire-fighting by internal and external facilities;
- Mobilizing first aid, hospitals and ambulances;
- Communication to authorities and third parties.

e) In addition to the above, Emergency Response procedures to address the following events:

- LNG leakage and spill
- Emergency evacuation of LNG in tanks and systems
- Gas detection
- Fire in the bunkering area
- Unexpected movement of the vessel(s)
- Unexpected moving of the truck
- Unexpected venting on the receiving ship or on the bunkering facility
- Loss of power

The PA Emergency Response Manual, as well as all documentation above shall be communicated to all parties involved in the bunkering operation including the planned emergency response team.

Regular reviews and updates of the Port Authority's emergency response and operating procedures should address organisational changes, responsibilities and levels of competency required to ensure safe operations at all times. This is generally part of the Management of Change processes of ports to identify external and internal changes that may affect established procedures, operating knowledge and level of services.

7. Roles and responsibilities

7.1. Personnel involved in LNG Bunkering

When LNG bunkering operations will take place in a Port environment, there would be personnel from the Port and from the wider onshore area that might be involved or related to these operations, such as:

Port staff, both from managerial and onsite, like for example stevedores, tug crews, crane operators, personnel who could regularly be located in the vicinity of the LNG bunkering operations area or personnel who may be affected by any spills or releases from the area,
Local and national authorities, for example personnel who would undertake a significant portion of their time within the LNG bunkering operation's area.

There are also personnel directly involved on the LNG transfer process, included, and not limited to:

Crew, including crew temporarily ashore, of the RSO and LBV / LBB,
Personnel involved in the supply of the LNG, normally operators at an LNG Terminal or at a small LNG liquefaction plant.
Personnel involved in the delivery of the LNG, from the operating organisations within Ports, such as BFOs, road tanker drivers, or the crew of an LBV/LBB or the tug propelling a LNG bunker barge when used as LBV/LBB.

There are personnel indirectly involved in the bunkering process that may require a basic understanding of the fuel and the bunkering process, such as:

Shipping company personnel with responsibility for ordering fuel,
Technical and operations superintendents from shipping companies with responsibility for ship equipment, maintenance and scheduling,
Charterers.

And there could be individuals that could be temporarily located at a Port area where LNG bunkering might take place, such as:

Shore based personnel of the ship owner or operating company who occasionally enter the LNG bunkering area, including ship's agent,
Visitors, including staff from companies related to the LNG bunkering operation, contractors, staff who may only spend a short amount of time in the area,
Emergency services personnel working at the Port / Terminal who need to plan responses to potential hazardous scenarios,
Local and national authorities who may occasionally visit the facility for their own purpose, for example, regulatory compliance purposes.

7.2. Key stakeholders in LNG Bunkering operations at Ports: roles and responsibilities

From the myriad of personnel that relates to the LNG bunkering operations, the following list represents those who have a key role and hold key responsibilities for the safe bunkering operation within Ports:

Port Authority and National Authority / Competent Authority.

Bunkering Facility Operator's Personnel, in particular, the Person In Charge PIC.

Receiving Ship Operator, in particular, the designated Responsible Person.

Terminal Operator when applicable.

7.2.1. Bunkering Facility Operator (BFO) role and responsibilities

The LNG BFO, as the organisation delivering the LNG bunker fuel to the RSO within the Port, should be responsible for the operation of the LNG bunkering installations including:

Planning of the specific operation (liaising with the RSO operator and the Terminal representative where the LNG bunkering takes place when the Terminal is named responsible for planning)
Operation of the facility in line with plans and procedures, and
Maintenance of the bunkering equipment.

The BFO would have the responsibility to appoint an individual person as responsible for the delivery and transfer of LNG bunkers and the associated bunkering documentation. This person is in overall charge of the LNG bunkering operation and is named as the "Person In Charge" or PIC or ROS ("Responsable de la operación de suministro").

Operation Responsible (BFO-PIC / ROS) roles and responsibilities:

A PIC/ROS should be agreed by the RSO, the BFO and the TO.

For STS transfer method, the PIC role should be undertaken by the Master of the LBV or LNG bunker barge, although it could also be agreed between BFO and RSO.

For TTS and PTS transfer methods, a person of equivalent authority should be agreed as PIC.

The PIC should have an appropriate level of competence and be accepted to operate in the bunkering location. This may require authorisation or certification to act as PIC for bunkering operations issued by the Competent Authority / PA or other Authority with jurisdiction over the bunkering operation.

The identity of the PIC shall be communicated to all parties involved in the bunkering operation before bunkering begins. The PIC shall be responsible for ensuring that agreed bunkering operating procedures are followed and that operations comply with all applicable regulatory requirements.

The PIC should be responsible for the bunkering operation and for the personnel involved in all aspects of the bunkering operation, until completion of the operation.

The PIC should ensure that:

- Relevant approved procedures are properly applied, and
- Safety standards are complied with, in particular, within the hazardous zone and safety zone.

To achieve this, the PIC should be responsible for:

Starting and stopping the bunkering,
Ensuring that all required communications are made with the Implementing Authority,
Ensuring that specific operating procedures are followed, and that the operation is conducted in compliance with all applicable port regulatory requirements, making sure that any declaration and bunkering documentation and required checklists are completed,
Ensuring that all required reports are made to the appropriate Authorities,
Agreeing the mooring arrangement, confirming with the RSO's Master or his representative (a responsible person designated by the RSO Master), the correct relative location of RSO and LBV or Barge vessels and, moorings and placement of fenders, for when STS method is applied. Mooring arrangements should consider the hazardous zones planning of both vessels (LBV or LBB and RSO).
Confirming that SIMOPS, where applicable, have been approved by the Implementing Authority prior to commencement;
For STS, monitoring mooring arrangement integrity (in communication with mooring master);
Conducting a pre-operation safety meeting with the responsible officers of both the bunkering facility, the receiving ship and the Terminal representative where the LNG bunkering operation takes place.
Assessing current and forecast meteorological conditions for the duration of the bunkering operation, ensuring all safeguards and risk prevention measures are in place prior to initiating the fuel flow, to ensure that operation will remain within the accepted environmental window for the duration of bunkering and the meteorological limits of the Terminal/Quay.
Monitoring communications throughout the operation;
Being familiar with the results of the location risk assessment and ensuring that all specific risk mitigation means are in place and operating (water curtain, fire protection, etc.), including security and safety zones;
Ensuring the safe procedures are followed and purging and leak testing of the bunkering system prior to transfer is successfully completed;
Responsible for the activation of Emergency Procedures related to the bunkering system operation, ensuring that the transfer system is in good order and that the emergency shut-down system is properly connected and tested;
Ensuring safe procedures are followed and the connection of liquid and vapour transfer hoses, safe connection/disconnection of the transfer system and associated Emergency Release Systems (ERS) is successfully completed;
Ensuring the safe procedures are followed for drainage and purging of the bunkering system prior to disconnection;
Monitoring fuel transfer and discharge rates including vapour management;
Supervising disconnection of liquid and vapour hoses/pipes;
Supervising unmooring and separation of ships or in the case of truck bunkering, departure of the truck
Supervising deployment/return of fenders and/or additional support utility to the bunker ship.
Advising the RSO Master or his representative when bunkering is completed;

7.2.2. Receiving Ship Operator (RSO) roles and responsibilities

The RSO has responsibilities for bunkering operation including:

- Informing the BFO and the PA in advance for necessary preparation of the bunkering operation, and
- Attending the pre-bunkering meeting to ensure:
  - Compatibility with local requirements,
  - Quantity and flow rate of LNG to be bunkered, and
  - Coordination of crew and safety communication systems and procedures.

The Master of the RSO:

- Retains overall control over his vessel for the safe operation of the ship throughout the bunkering operation.
- If the bunkering operation deviates from the planned and agreed process the Master retains the right to terminate the process.

The Master of the RSO has the overall responsibility for the following aspects. However, the Master can delegate the following aspects to the PIC or to other Responsible Person designated by the Master from within his crew, while retaining the overall responsibility for the bunkering operation within his ship.

The Master or his designated Responsible Person (RSO-PIC) have the following responsibilities:

- Take care of the LNG bunkering operations onboard the ship and liaise with the PIC, informing the PIC of any change of pre-agreed SIMOPS activities onboard the RSO,
- Approving the quantity of LNG to be bunkered,
- Approving the composition, temperature and delivery pressure of LNG that is available from the bunkering facility operator (aspects of this may have been agreed prior to the bunkering operation as part of the LNG supply contract),
- Ensuring that the approved safe bunkering process is followed including compliance with any environmental protection requirements required by international, national or local Port regulations,
- Agreeing in writing the transfer procedures including cooling down and if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred,
- Completing and signing the required LNG bunkering checklist.
- Keep safe minimum manning requirements for when simultaneous operations are taking place during LNG bunkering and ensure that as a minimum, the following manning is in place:
  - A Single Person in charge of the LNG bunkering operation on board (RSO-PIC), in case it is not the Master, the designated responsible person by the Master
  - Permanently manned bridges in accordance with the requirements of the STCW (Seafarer's Training, Certification & Watch keeping). However, it should be noted that when operations involve a small LBV the smaller vessel may not maintain a separate mooring watch and may rely on the Receiving Vessel's Mooring Master to ensure a safe watch is maintained. This issue should be addressed in the pre-bunkering safety meeting.
  - The engine control room on the Receiving Vessel should be manned with the propulsion system readily available for immediate use.
  - The bunkering controls should be manned full time during the bunkering operation.

7.2.3. Port Terminal's roles and responsibilities

The term "terminal" must be understood as any organization responsible for the location of the bunkering and for LNG bunker control zones on the shore side during LNG bunkering and, if applicable, the terminal activities simultaneous with LNG bunkering in the safety zone.

The role given to each Terminal by the Competent Authority would determine their scope of responsibilities in the LNG bunkering of ships calling at the terminal.

In general, IAPH considers that for TTS method, the terminal is responsible for the location where LNG Bunkering operation is physically performed, while the BFO would be responsible for complying with the requirements to secure a safe and compliant LNG bunkering operation within the Terminal.

And in case of LNG transfer method being **PTS,** the Terminal would hold overall responsibility for the safety of LNG bunkering operation within its premises.

While **in case of STS** being the transfer method adopted, both options could be possible: a clear division of responsibilities is documented on the IAPH LNG Bunkering Checklists (see section 3.5), dated June 2019, for STS, where LNG Bunker checklist – Ship To Ship – Version 3.7a is recommended for when Terminals are responsible for the location of bunkering only, while Version 3.7b is recommended for when Terminals are overall responsible for the location, control zones, and all activities related to the LNG bunkering operations.

The IAPH checklists do document all the responsibilities that need to be taken by parties during LNG bunkering operation at Port and its applicability would depend on the role that the Competent Authority assigns to each party.

The Competent Authority could determine what the terminal's role and responsibilities should be in every case.

As per most recent IAPH publications, Ports could introduce an LNG Ready Terminal designation, as a means to qualify what a Terminal should comply with in order that the Competent Authority could grant permission for LNG bunkering operations to be performed within its premises. The PA would state what the Terminal or the delegated BFO would be asked to have in place to be considered prepared to comply with the requirements for a safe LNG bunkering operation at Port. The IAPH suggest that the Terminals or BFOs would comply if it:

has incorporated procedures into its safety management system to ensure the proper level of preparedness for the handling of LNG-fuelled vessels.
can deliver terminal-specific and location-specific safety measures to be incorporated into the so-called Joint Bunkering Management Plan (JBMP) described in [B II C3.1] of this guidelines, such as (but not limited to) weather conditions and limitations, potential restrictions with regard to simultaneous operations, and means of communication;
can review and agree upon a JBMP;
can review, contribute to and agree upon SIMOPS and risk mitigation;
can adjust the operational process to deal with safety measures necessary for the safe handling of the LNG-fuelled vessel, with and/or without simultaneous operations;
can adjust the operational process to deal with the safety measures necessary for safe, JPO compliant LNG bunkering;
has prepared the terminal incident response organisation to deal with an LNG-related incident;
has instructed terminal personnel on the procedures and safety measures;
has trained relevant personnel;
has established proper interaction and communication with all the relevant terminal personnel;
has established proper interaction and communication with all the relevant vessels.

As per the IAPH guidance, the LNG Ready Terminal designation can be used by a terminal to demonstrate its level of preparedness for handling LNG-fuelled vessels. A port may decide to use the LNG Ready Terminal designation in its spatial planning and safety framework for LNG bunker activities.

7.2.4. Key stakeholders shared responsibility

Before the LNG bunkering operation commences, the following key stakeholders:

- Operation responsible (BFO-PIC/ROS)
- Receiving ship operator person in charge (RSO-PIC)
- Terminal Representative (TO/COS)
- Master of LBV / Representative of BFO (if different from PIC)

Should:

1. Agree in writing on the transfer procedures, including the maximum loading or unloading rates;
2. Agree in writing on the action to be taken in the event of an emergency;
3. Complete and sign the LNG bunkering checklist for the applicable transfer method.
4. Comply with the Port Authority and terminal requirements/regulations.
5. Fulfill the obligations imposed by the RD 171/2004 “Coordinación de Actividades Empresariales.

7.3. Crew and Personnel Competence, Qualification and Training for LNG bunkering operations

7.3.1. Training and Competency Industry Guidelines

There are five main references in maritime industry that recommends best practices for training and creating competencies for personnel involved in LNG bunkering operations at Ports:

International Maritime Organization IMO: STCW

The International Convention on Standards of Training, Certification and Watchkeeping (STCW) for Seafarers, 1978, sets the minimum qualification standards for masters, officers and watch personnel on seagoing merchant ships and large yachts to which the IMO's regulations apply.

IMO Resolution MSC.396(95) adopted on 11th June 2015 amended the STCW 1978 Convention introducing requirements for personnel that work on ships that are subject to the IMO IGF Code, gas-fuelled ships included.

These requirements are applicable to personnel involved in all modes of LNG bunkering when a ship is involved: STS, TTS and PTS (including Terminal To Ship) LNG bunkering operations.

The STCW Chapter V refers to "Special training requirements for personnel on certain types of ships" and includes gas-fuelled ships among such types.

STCW Regulation V/3 of Chapter V details what the minimum requirements are for the training and qualification of masters, officers, ratings and other personnel on ships subject to the IGF Code.

STCW Code Section A-V/3 of Chapter V specifies Basic Training (in its Table A-V/3-1) and Advanced Training (in its Table A-V/3-2) and the standard of competencies required.

The STCW regulations are mandatory for crew onboard ships subject to compliance with IGF Code. We recommend same requirements to apply to crew onboard RSO, LBB, LBV, as follows:

- Seafarers responsible for designated safety duties associated with the care, use or in emergency response to the LNG bunkering operation on board RSO, LBB or LBV to have completed basic training in accordance with the provisions of STCW Code Section A-V/3 paragraph 1, 2019 edition.
- Masters, engineer officers and all personnel with immediate responsibility for the care and use or in emergency response to the LNG bunkering operation on board RSO, LBB, LBV to have completed advanced training in accordance with the provisions of STCW Code Section A-V/3 paragraph 2, 2019 edition.
- Masters, Engineer Officers and all personnel on board an LBV or LBB must have completed basic or advanced training in accordance with the provisions of STCW Code A-V/1-2 and licensed accordingly.

For TTS, Truck drivers must be certificated against ADR, but for the bunker transferring competence, both TTS and PTS, would require adhering to local Port Authorities specific requirements. At this time, the Spanish national level requirements are fulfilled by SEDIGAS courses (TTS, PTS, etc.) and LNG non-bunkering specific certifications. Soon a competence framework will be approved by an official body (INCUAL) to allow for specific accreditations and training in Spanish ports regarding LNG bunkering operations. This framework has been designed to allow as well for validation processes for the personnel currently developing bunkering operations.

Society for Gas as a Marine Fuel SGMF

The Society for Gas as a Marine Fuel (SGMF) has created a very comprehensive LNG Competency and Assessment Guideline for LNG Bunkering of Ships in its version 2.0, document FP04-02 dated September 2017.

We would refer to these guidelines in this section as they represent best practice in the Maritime Gas As Fuel Industry, covering all possible stakeholders that can be directly or indirectly involved in LNG bunkering at Ports, both onshore and on board ships.

International Association of Classification Societies IACS

The IACS (International Association of Classification Societies) LNG Bunkering Guidelines, June 2016 edition, Section 4.3. provides guidance on how to raise awareness of Crew and Personnel on board ships. It gives information about the required competencies and training for taking part in LNG bunkering operations, by referencing the STCW/7/Circ.23 “Interim guidance on training for seafarers on board ships using gases or other low flashpoint fuels”, as applicable to seafarers on board gas-fuelled ships, which was subsequently superseded by the entry into force of the IMO IGF Code and Resolution MSC.396(95) and MSC.397(95).

The IACS document also suggest that on board personnel involved in LNG bunkering operations undertake specific safety training that is prepared based on the conclusions and outputs of the risk studies performed at the Port.

European Maritime Safety Agency EMSA Guidelines

Recognising the complexity of the LNG bunkering interface between onshore and maritime domains, and within onshore and maritime domains themselves, EMSA has created a LNG Bunkering Training Matrix to better assist all parties willing to develop qualification and training schemes for all personnel involved, listing the relevant legal minimum requirements applicable to LNG bunkering.

We are guided by the EMSA LNG Bunkering Training Matrix in these Guidelines and would adopt it, complemented by recommendations from SGMF and IACS where applicable, and as shown in paragraph 7.3.3.

EN ISO 20519 Section 8

EN ISO 20519 is referred throughout this Guidance as the standard that should serve as a basis for certification, accreditation and quality assurance of all stakeholders. Its section 8 describes requirements for Personnel Training for personnel involved in bunkering operations on vessels as well as for personnel providing LNG from Port or mobile facilities.

7.3.2. The importance of training for safe, effective and compliant LNG bunkering operation

The variety of personnel involved, from onshore operators to shipping personnel and crew onboard ships, to Port employees and land-based maritime specialists and emergency services plus the public, whether passengers on ships or people at the Port, makes managing a safe, efficient and environmentally compliant LNG bunkering operation more challenging. The delivery of a suitable level and quality of training to each person commensurate with the individual’s required level of responsibility would allow Port Authorities to ensure that all risks are managed.

All personnel dealing with LNG bunkering operations and handling of LNG, need to be educated and trained so that they can acquire a level of competence commensurate with their role and responsibilities in LNG bunkering operations at Ports.

As mentioned in section 7.2.1., the types of personnel that can be involved in LNG are varied:

Personnel from the Port and from the wider onshore area that might be involved or related to these operations,
Personnel directly involved on the LNG transfer process,
Personnel indirectly involved in the bunkering process that may require a basic understanding of the fuel and the bunkering process,
Individuals that could be temporarily physically at a Port area where LNG bunkering might take place.

Part of the challenge in making LNG bunkering safe at Ports resides in the fact that, as shown above, there are many people who could potentially interface, directly or indirectly, while LNG is being transferred within the Port, and these people will generally have varied backgrounds, some more, some less experience related to handling LNG. Therefore, training of personnel is required to ensure that people involved:

1. Gained full awareness of the hazards of handling LNG and of potential ways to mitigate them in real operations,
2. Understand how the occurrence of incidents could be reduced or minimised as much as possible and their individual contributing role,
3. Understand and/or get familiar with each person's assigned responsibilities and the procedures that are to be implemented to perform LNG bunkering safely.

The delivery of the right training content at the right level of understanding to each person would be necessary in order to make them confident and obtain the qualification against the competency required to perform their role.

7.3.3. Personnel involved in LNG bunkering at Ports who may require training and competency qualification

Guided by the recommendations of the SGMF LNG Competency and Assessment Guidelines of September 2017 and the recommendations from IACS and EMSA, the following Table 7.1 presents all the potential functional roles that could be involved in LNG bunkering operations at Ports, and for whom a training program would be recommended:

Table 7.1 Potential roles that may require LNG bunkering specific training. Source: Lloyd's Register 2020

LNG Bunkering Stakeholders		Functional Role	Code
RSO	Shore Personnel	Company Superintendent – Receiving Ship Operator	SP
	RSO Personnel	**Designated PIC (Person In Charge at RSO) / POAC**	**D-PIC**
		Manifold Watch (Crew Member)	MW
		Master	M
		Engineers – ECR, Bunkering Control Management	E
		Officers – Bridge's manning	B
		Crew in charge of Vessel's Moorings	MR
		Other Crew Members	CW
BFO	LBB / LBV for STS Transfer	**PIC: Person In Charge**	**PIC**
		Master	MB
		Hose Watch	HW
		LNG Quality and Quantity (Q&Q) Specialist	QQ
	Bunker Station for PTS Transfer	**PIC**	**PIC**
		LNG Supplier's Manager	SM
		Hose Watch	HW
		Q&Q Specialist	QQ
	Truck for TTS Transfer	**PIC**	**PIC**
		LNG Supplier's Manager	SM
		Hose Watch	HW
		Road Tanker (Truck) Driver	TD
		Q&Q Specialist	QQ
PORT	Personnel Employed by the Port or by the Terminal within the Port	Port Manager or Supervisor	PM
		Port Worker	PW
		Port Security	PS
		Emergency Services	ES
Marine Specialists		Class Society's Surveyors and other Specialists Charterers Ship Owner (RVs/LBB/LBV) Superintendents	CS CH OW
Other Stake-holders		Emergency Services Local / National Authorities Representatives Truck Drivers Other Port Visitors Passengers	ES PA D PV P D PV P

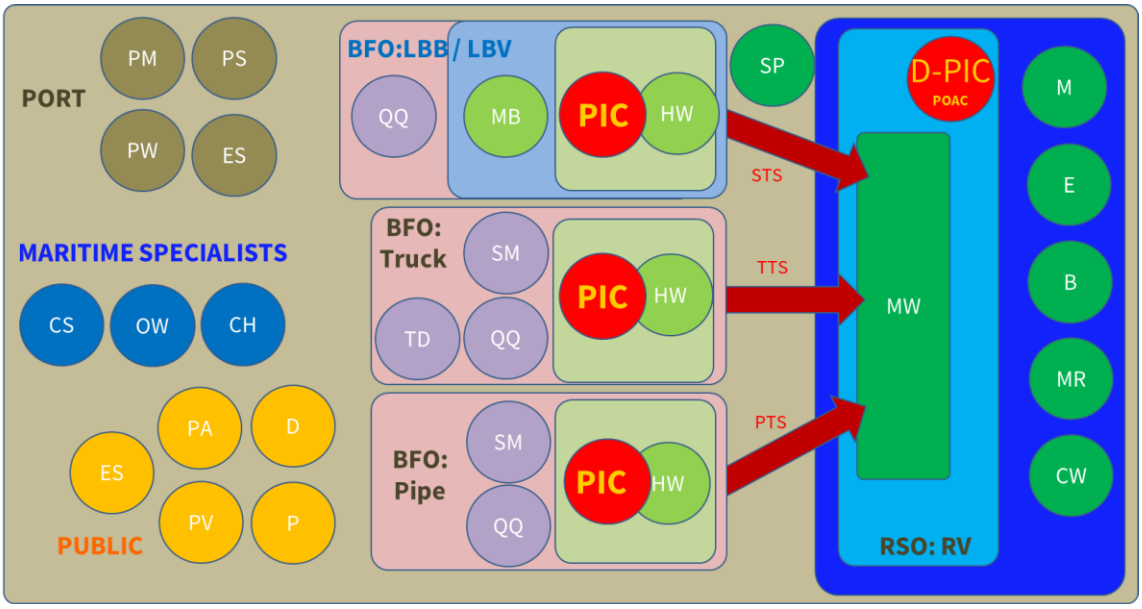

Figure 7.1 Schematic of potential roles that may require LNG bunkering specific training. Source: Lloyd's Register 2020

For the RSO, the minimum manning requirements onboard during LNG bunkering operations should include:

- A SINGLE Person In Charge (PIC) or also called Person in Overall Advisory Control (POAC), should be identified and preferably be part of the bunker vessel's complement.
- A Superintendent assisting the PIC, managing the Receiving Vessel Operations who should be well versed with the receiving ship's bunkering system; this is called the RSO Receiving Ship Operator.
- Permanently manned bridges in accordance with the requirements of the STCW (Seafarer's Training, Certification & Watch Keeping). However, it should be noted that when operations involve a small bunker tanker the smaller vessel may not maintain a separate mooring watch and may rely on the Receiving Vessel's Mooring Master to ensure a safe watch is maintained. This issue should be addressed in the pre-bunkering safety meeting.
- The engine control room on the Receiving Vessel should be manned with the propulsion system readily available for immediate use.
- The bunkering controls should be manned full time during the bunkering operation.

7.3.4. Mapping regulatory regimes with personnel involved in LNG bunkering of ships

The Figure 7.2 below extracted from the EMSA Guidelines, depicts the complexity of the LNG Bunkering interface and the many stakeholders that interact. For each category of stakeholder there are different regulatory instruments driving the creation of training and competencies to specific personnel involved directly or indirectly in the LNG Bunkering operation.

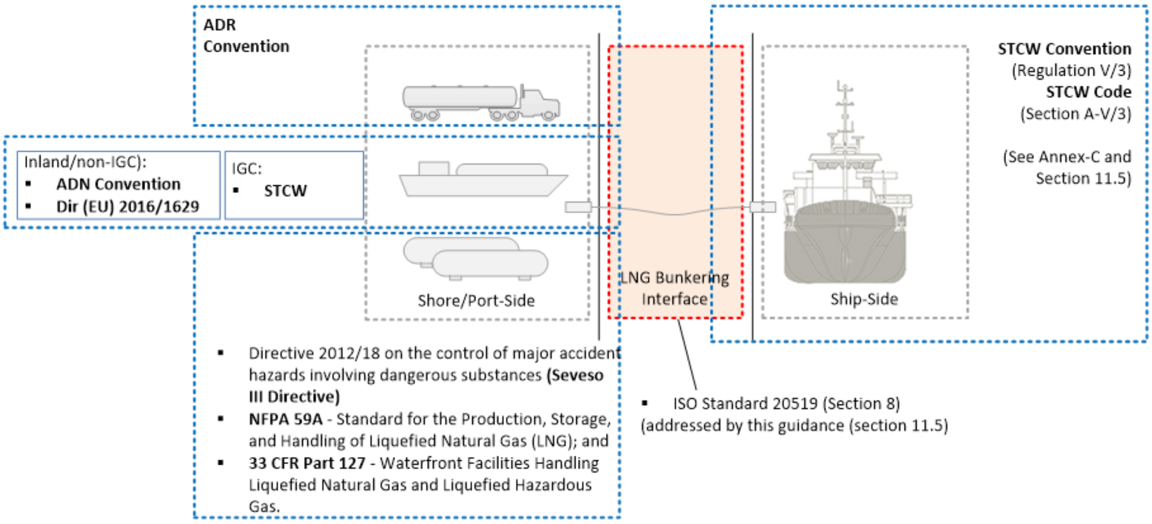

Figure 7.2 EMSA Source - Applicable references in Competencies and Training requirements – complexity of the LNG Bunkering interface

In order to deal with this complexity, the EMSA's LNG Bunkering Training Matrix will be used as reference. Table 7.2 and Table 7.3 below show the requirements reported by EMSA plus complementary applicable requirements by the IMO, IACS and SGMF. The EMSA tables have also been modified to include all the functional roles identified in 7.3.3. above.

Table 7.2 LNG bunkering training matrix for maritime personnel. Source: Lloyd's Register 2020

DOMAIN	ACTIVITY	CATEGORY	REGULATORY INSTRUMENT ON TRAINING & COMPETENCES
MARITIME	LNG Carriers LNGC (for transporting LNG)	All Ship's Crew	IMO IGC Code IMO STCW Convention IMO Model Course – Advanced Training for Liquefied Gas Tanker Cargo Operations Directive 2008/106/EC on the minimum level of training seafarers
	LNG Bunkering Vessels: RVs and LBB / LBV	A. Person In Charge PIC (from BFO) B. Designated PIC C. Manifold Watch Person (RSO) D. Hose Watch (LBB/LBV) E. Masters (RSO and LBB/LBV) F. Engineers at ECR and Bunkering Controls RSO G. Officers at RSO's Bridge H. Other Crew on RSO (i.e. at Moorings) I. All other Crew on RSO, LBB and LBV	IMO Res MSC392(95): IGF Code IMO IGC Code IMO Res MSC395(95): amendments to SOLAS Convention IMO Res MSC.396(95): amendments to STCW Convention & Res MSC.397(95): amendments to STCW Code IMO STCW.7/Circ.23 on interim guidance on training for seafarers on board ships using gases or other low-flashpoint fuels STCW Advanced Training recommended for Personnel Categories A, B, C, D, E, F, G, H and any Crew member with responsibilities in Emergency Response. STCW Basic Training recommended for Personnel Category I SGMF LNG Bunkering Competency Guidelines

Table 7.3 LNG bunkering training matrix for shore personnel. Source: Lloyd's Register 2020

DOMAIN	ACTIVITY	CATEGORY	REGULATORY INSTRUMENT ON TRAINING & COMPETENCES
PORTS	LNG Bunkering Operations	Personnel involved in LNG bunkering operation, such as: J. Port Manager or Supervisor K. Port Worker L. Port Security M. Emergency Workers And shore-based personnel from ships as follows: N. Receiving Ship Operator's Superintendent O. LNG Supplier's Manager P. Q&Q Specialists	ISO TS 18683 (2015-01-15) Guidelines for systems and installations for supply of LNG as fuel to ships – Chapter 10 Training ISO/IS 20519 LNG Bunkering Standard Chapter 8 Personnel training CEN/TC 282 on LNG equipment and installation: ad hoc group on training IASC Recommendation N0.142 on LNG Bunkering Port Regulations on bunkering an on dangerous goods IAPH Guidelines and Checklists for STS, TTS and Bunker Station to Ship Directive 2012/18 on the control of major accident hazards involving dangerous substances (Seveso III Directive): recommended when Seveso III is recommended, as per this Guide Section 6.1 CCNR: Standard for a LNG bunker checklist Truck to Ship Edition 1.0 SGMF LNG Bunkering Competency Guidelines
	Transport of LNG	Q. Road Tanker (Truck) Driver	ADR Agreement Directive 2008/68 on the inland transport of dangerous goods ISO/IS 16924.2 LNG stations for fuelling (19.5 Training) – CEN/TC 326 refuelling stations SGMF LNG Bunkering Competency Guidelines
	During LNG Bunkering operations within Port	Public within Ports that might become involved or affected by the LNG bunkering operation: • Emergency Services • Local / National Authorities Representatives • Truck Drivers • Other Port Visitors • Passengers	Port Regulations and Safety Management System (SMS) Health & Safety local regulations for workers SGMF LNG Bunkering Competency Guidelines

In addition, the following shore-based personnel are recommended to follow the requirements of SGMF FP04-02_Ver2.0_Bunkering-of-Ships-LNG-Competency-and-Awareness-Guidelines_September 2017:

- Class Society's Surveyors and other Specialists
- Charterers
- Ship Owner (RVs/LBB/LBV) Superintendents

MATRIX for Inland Waterways, Railway and LNG Terminals

For training and competencies of personnel working in Inland Waterways, on Railways and in LNG Terminals, involved in LNG bunkering for ships, we recommend to be directly guided by EMSA Guidance on LNG Bunkering to Port Authorities/Administrations, Section 16.2.

7.3.5. Creating a Competency Framework for LNG bunkering: SGMF Guidance

Since several domains interface in LNG Bunkering operations at Ports, reaching harmonised competencies and designing the appropriate training for each of them will secure a safer and environmentally friendly operation. This is a challenge that has been recognised by SGMF and IACS. SGMF has since created a methodology to identify:

- All personnel that are involved and who require training.
- A list of 4 Competency Levels, namely:
    - **MANAGE**: individuals that are responsible for the personnel who will be engaged in the operation or the area where this operation takes place, along with the administration, planning and implementation of the supply of fuel (LNG), on behalf of the receivers, suppliers or port authority/regulatory bodies,
    - **DO**: individuals who will be engaged directly in the LNG/gas transfer and who may supervise other individuals engaged in the activity,
    - **ASSIST**: individuals that support the activities required in the transfer of LNG/gas but are under the direct supervision and direction of the DO level,
    - **RESPOND**: individuals who need to be familiar with and understand the hazards associated with LNG and the actions that need to be implemented in an emergency situation.
- Two additional competency levels envisaged for roles that are very specific and/or indirectly or infrequently involved:
    - **SPECIALIST**: training required to cover very specific skills required of a few individuals,
    - **BESPOKE**: training required for staff supporting the bunkering operation who do not immediately fall into the four competency levels described above.
- Areas where personnel would demonstrate competence, called "modules" by SGMF Guide:
    - Operating and regulatory framework
    - Ensuring a safe environment
    - Checking equipment as fit for purpose
    - Connection and testing
    - Transferring LNG
    - Draining, disconnection and storage
    - Responding to Emergencies
    - Quantity & Quality
    - Port & Ship Specific

- List of specific tasks for personnel to demonstrate competence, depending on their competency level /role: each 9 modules above would have a set of tasks assigned to them.
- An Assessment guide to evaluate personnel's competency, that is based on 4 primary levels defined as:
    - **INTERPRETS**: this level corresponds to roles that require the highest skilled and competent individuals to undertake them. The individuals are assessed on their ability to critically examine information to make judgements, interpret novel situations, plan procedures and troubleshoot events.
    - **APPLIES**: these individuals are assessed on their ability to use taught concepts or knowledge in a new or similar situation.
    - **UNDERSTANDS**: these individuals are assessed on their ability to comprehend the meaning and interpretation of instructions and problems.
    - **KNOWS**: this level corresponds to the roles that require the lowest skilled and competent individuals or the unskilled. The individuals are assessed on their ability to recall learned information.

Based on the above framework and the SGMF's own recommendations, we recommend a level of competency for each of the personnel identified in section 7.3.3., as shown in Table 7.4 below:

Table 7.4 Recommended levels of training by competency of personnel. Source: Lloyd's Register 2020

LNG Stakeholders	Bunkering	Functional Role	Role	Recommended Competency level
RSO	Shore Personnel	Company Superintendent – Receiving Ship Operator	SP	BESPOKE
	RSO Personnel	**Designated PIC (Person In Charge at RSO) / POAC** Manifold Watch (Crew Member) Master Engineers – ECR, Bunkering Control Management Officers – Bridge's manning Crew in charge of Vessel's Moorings Other Crew Members	**D-PIC** MW E B MR CW	**DO** ASSIST MANAGE MANAGE & DO MANAGE & DO ASSIST RESPOND
BFO	LBB / LBV for STS Transfer	**PIC: Person In Charge** Master Hose Watch LNG Quality and Quantity (Q&Q) Specialist	**PIC** MB HW QQ	**DO** MANAGE ASSIST SPECIALIST
	Bunker Station for PTS Transfer	**PIC** LNG Supplier's Manager Hose Watch Q&Q Specialist	**PIC** SM HW QQ	**DO** MANAGE ASSIST SPECIALIST
	Truck for TTS Transfer	**PIC** LNG Supplier's Manager Hose Watch Road Tanker (Truck) Driver Q&Q Specialist	**PIC** SM HW TD QQ	**DO** MANAGE ASSIST DO & ASSIST SPECIALIST
PORT	Personnel Employed by the Port or by the Terminal	Port Manager or Supervisor Port Worker Port Security Emergency Services	PM PW PS ES	MANAGE RESPOND SPECIALIST SPECIALIST
OTHER MARITIME SPECIALISTS		Class Society's Surveyors and other Specialists Charterers Ship Owner (RVs/LBB/LBV) Superintendents	CS CH OW	BESPOKE BESPOKE BESPOKE
PUBLIC		Emergency Services Local / National Authorities Representatives Truck Drivers Other Port Visitors Passengers	ES PA D PV P	SPECIALIST RESPOND RESPOND RESPOND RESPOND or no training required

The SGMF Guidelines assigns a specific list of competences for each competence level and per area or module of activity for each individual, aligned with the individuals' recommended overall competency level described in the table above.

We recommend that the SGMF Guideline is applied to establish the complete Competency Framework for all personnel involved in LNG Bunkering operations within Ports as per section 7.3.3.

8. Preliminary site locations analysis by Port Authorities

Port Authorities could analyse and evaluate locations at their Ports where the transfer of LNG to ships could be made safe and acceptable to them and their regulators under preliminary conditions.

Site locations preliminary analysis would be carried out in the fixed infrastructure and on the interfaces between Port designated infrastructure and ships (LBV, LBB, RSO) at the planned LNG bunkering operation location/s.

The analysis will determine the feasibility to undertake LNG bunkering operations within the LNG bunkering control zones**,** although is not a substitution for the licensing and authorization process described in Book II.

The safety zones tables included in this section 8 provides the starting point (baseline) for the Port Authority to evaluate and select potential bunkering locations within the Port without receiving technical information on the type and size of the bunkering operation.

The tables can be used for evaluating “safety zone” calculations from bunker licence applicants – allowing comparison of the assumptions, mitigating and exaggerating circumstances given the technical and safety features of the bunkering system under review.

This means that the safety zone distance recommended in the tables can remain as it is and be adopted for the preliminary safe bunkering zone delimitation within the Port, provided all the technical, environmental and safety features described in the tables are aligned with the bunkering system and bunkering operation under review.

A recommended workflow to implement a preliminary site location(s) analysis would be:

Determining whether the planned LNG bunkering operation would fall under Seveso III lower or upper tiers is considered a good precautionary practice by Port Authorities. If any LNG bunkering operation would fall within the tiers, the Port Authority might consider complying with very specific and stringent Seveso III required analysis. A recommendation to evaluate this can be found in [C 8.1].

The Port Authority should get familiar with the requirements set in tables 8.2 and 8.3 and adopt the safe distances recommended within them. This to determine what areas within the Port could be preliminarily considered for LNG bunkering operations to take place and their size.

A preliminary security zone could be determined following the guidance detailed in 5.4.3.

A preliminary Marine Zone / Marine Exclusion Zone could be determined following the guidance detailed in 5.4.4., noting that this zone could be considered as equivalent to the security zone when over water as opposed to on land premises. In general, it is expected that the Port would prepare plans and rules to restrict other shipping’s passing distance and speed around a safety zone when LNG bunkering operations are taking place within it.

After a pre-calculated Safety Zone distance has been considered for determining LNG bunkering areas, the need to perform risk assessments would still apply as detailed in section 5.3. and table 5.5. for the specific LNG bunkering operations that are to be approved within the designated areas. The risks assessments serve to help understand and prevent the risk (i.e. a large leak) from happening. These studies are also complementary to the Safety Zone, in terms of defining the mitigating and recovery actions (i.e. emergency response).

8.1. Port fixed Infrastructure preliminary analysis (SEVESO III applicability)

Terminal infrastructure is to be constructed and operating according to SEVESO III European Directive 2012/18/EU dated 4 July 2012 as transposed to Spanish RD840/2015 and EIA Directive (2011/92/EU as amended), where applicable.

The interpretations for reviewing LNG bunkering against the Seveso III directive is discussed at some length in Chapter 4.2 (High Level Instruments) of the [EMSA] Guidance on LNG Bunkering to Port Authorities.

However, the EMSA guideline falls short in recommending an approach to assess the envisaged LNG bunkering operations against the different Seveso categories (i.e. exempt, lower tier, higher tier), and subsequently determine whether or not the Directive would be applicable to the specifics of the LNG bunkering operations at Port.

Recognizing this gap, Lloyd's Register has developed its own guidance for Port Authorities, as shown in Table 8.1. It gives Port Authority the necessary criteria to perform their preliminary analysis of the level of compliance of their planned location with SEVESO III, therefore, would serve for Ports to analyse what areas within their premises could be best suited to their bunkering operation needs while being able to make them safety compliant. Otherwise, this could be of value for Ports to plan their LNG bunkering operations differently in order to make them be Seveso III Exempt.

Seveso III Guide Nomenclature:

- **Average weekly "LNG mass holding and bunkering time LMHBT"** is an index that helps evaluate the applicability of Seveso III for mobile LNG bunkering - making them comparable to the mass criteria applied to fixed LNG storage tanks. **It represents the philosophy behind Seveso III of quantifying the foreseeable presence of dangerous substances such as LNG in order to identify and better manage the risks.**

The Port's foreseeable LNG exposure on a weekly basis can be represented by the following:

- LMHBT = (Mass of LNG in tonnes) * (holding + bunkering time)

For example, a fixed LNG tank with a 50-tonne capacity based on the maximum filling limit will have an LMHBT of 8,400 tonne-hour/week.

LMHBT = (50 tonnes) * (24 hours/day) * 7 (days/week) = 8,400 tonne-hour/week.

- Since LNG storage capacity actively used for bunkering will never be full for long periods of time, LR recommends a 75% capacity as the factor to be used in deriving the Seveso III lower tier and upper tier thresholds.

- The Seveso III lower tier threshold can be estimated as follows:

  LMHBT = (8,400 tonne-hour/week) * (0.75)
  LMHBT = 6,300 tonne-hour/week
  LR recommends that this value is used as Seveso III lower tier threshold for mobile LNG bunker tank(s).

- Similarly, the Seveso III upper tier threshold can be estimated as follows:

  LMHBT = (200 tonnes) * (24 hours/day) * 7 (days/week) * 0.75 = 25,200 tonne-hour/week.
  LR recommends that this value is used as Seveso III upper tier threshold for mobile LNG bunker tank(s).

Table 8.1 Lloyd's Register Guidance to assess LNG bunkering infrastructure against SEVESO III. Source: Lloyd's Register 2019

Seveso III Directive LNG Criteria					
Type of LNG Bunkering	**Seveso Substances other than LNG**	**Quantifying LNG**	**Seveso III Exempt**	**Seveso III lower tier**	**Seveso III upper tier**
Fixed LNG tanks					
1. Fixed(stationary) LNG Tank(s)	Apply Seveso substances summation rule (see flow chart below)	Sum up all the LNG tank capacities	If LNG mass < 50 tonnes Tank Volume <110m3	If 50 < LNG mass < 200 tonnes 110m3 < Tank Vol. < 440 m3	If LNG mass > 200 tonnes Tank Volume > 440 m3
2. Framed ISO container(s)					
3. Non propelled moored LNG bunkering barge		Derive the total LNG barge capacity			
Mobile LNG Bunkering tanks					
4. Parked LNG trailer(s)	Apply Seveso substances summation rule (see flow chart below)	Estimate the weekly "LNG mass holding and bunkering time"	If LMBHT < 6,300 tonne-hour/week In terms of volume LVBHT <13,860 m3-hour/week Approximately: **<63 bunkering trucks/week** (110m3, with 2 hours to conduct staging and bunkering)	6,300 < LMBHT < 25,200 tonne-hour/week in terms of volume 13,860<LVBHT<55,440 m3-hour/week Approximately: Trucks (110m3, 2 hour staging bunkering time) **63 trucks < lower tier < 252 trucks per week** **Bunker barge of 5,000 – 18,000 m3 capacity doing 1 bunkering per week.**	If LMBHT >25,200 tonne-hour/week In terms of volume LVBHT >55,440 m3-hour/week Approximately: **Upper tier > 252 trucks per week.** **Bunker barge of 5,000 – 18,000 m3 capacity doing 2 bunkering barge operations per week.**
5.LNG bunkering truck(s)					
6.LNG bunkering barge					
Recommended Actions for Port Authorities					
			Require the RA docs described in this Guide.	Refer the case to a designated Seveso III competent authority for further analysis and commentary.	Refer the case to a designated Seveso III competent authority for further analysis and commentary.

Determining whether the planned LNG bunkering operation would fall under Seveso III lower or upper tiers is considered a good precautionary practice by Port Authorities, as in case any LNG bunkering operation would fall within the tiers, the Port Authority might consider complying with very specific and stringent Seveso III required analysis**.**

The following flow chart (Figure 8.1) can guide Port Authorities on their review of the applicability of Seveso III Directive.

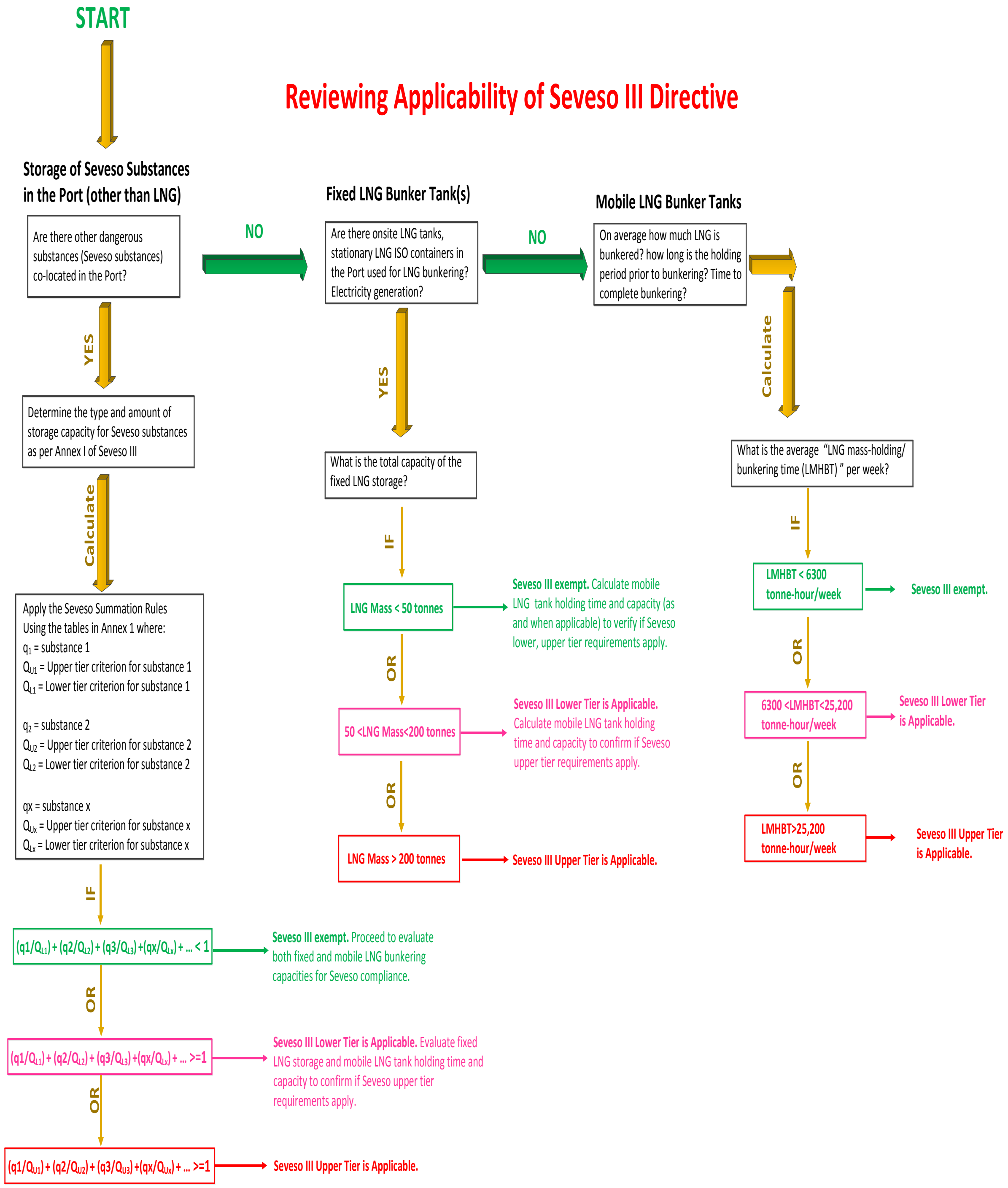

Figure 8.1 Reviewing applicability of Seveso III directive. Source: Lloyd's Register 2019

8.2. Port fixed infrastructure and Ships and Trucks interface preliminary analysis

The next action from Port Authorities to determine after deciding where LNG bunkering operations could be feasible and made safe, is to determine the size of the Hazardous Area Zone.

Table 8.2 provides the necessary guidance to apply to the chosen locations when examining their adequacy to become LNG bunkering operation safe zones, meaning zones where the interface between ships and Port could be managed safely during required operations. Hazards inherent to Fixed LNG Tanks at Port, LNG Bunkering Barge LBB and LNG Bunkering Truck LBT can be kept controlled following the requirements set in prescriptive regulations, as mentioned in the table, or against prescriptive distances as also shown in the table.

Table 8.2 Preliminary Hazardous Area Zone - Siting Matrix. Source: Lloyd's Register 2019

LNG System Component	Zone	Fixed LNG Storage Tank	LNG bunkering Barge	LNG bunkering Truck
1. Tank Relief Vent Termination	1,2	-Derived empirically using IEC60079:10. -Prescriptive requirements in NFPA 59A dependent on tank design conditions	- At least Breadth/3 or 6m in vertical height -At least B or 25m away from other areas	- At least 10 meters away from non-hazardous areas**
2. Ventilation outlets (i.e. termination of HAZ spaces)	1	-Not Applicable - as LNG piping, pumping equipment are not housed in enclosed spaces	-At least 3m from the outlet in all directions	-Not Applicable
	2		-At least 1.5 m on top of the zone 1 requirement (1.5+3= 4.5m total)	-Not Applicable
3. Bunker manifold valves and flange connections	2	-Derived empirically using IEC60079:10 -Prescriptive requirements in NFPA 59A dependent on tank design conditions	- At least 3m away from non-hazardous areas	- At least 3m away from non-hazardous areas**
4. Quick connect, disconnect couplings	1		At least 3m from the coupling in all directions	
	2		At least 1.5 m on top of the zone 1 requirement (1.5+3 = 4.5m total)	
5. Emergency release coupling	2		At least 3m away from non-hazardous areas	
6. Flexible hoses	2		At least 3m away from non-hazardous areas	
7. LNG tank (Internal Volume)	0	All tanks will have continuous amount of gas vapour while in use		
8. LNG tank (Insulation space, Annulus space)	1	Dependent on tank integrity* Apply NFPA 59A requirements or derive using IEC60079:10	Entire annulus space is considered zone 1	
9. LNG tank (external to tank)	2		-Non-hazardous if provided with a double wall arrangement. -Deck space	-Derived empirically using IEC60079:10
10. LNG pump, Compressors	1,2	-Derived empirically using IEC60079:10 -Prescriptive requirements in NFPA 59A	-Submerged LNG pumps, or positioned in enclosed spaces (LNG pump room)	-Derived empirically using IEC60079:10

8.3. Preliminary requirements for Ships and Trucks engaged in LNG bunkering operation at Port in Safety Zone.

Once the Hazardous Area has been established and requirements for LNG System Components set, and the Safety Zone requirements for LNG System components within it are set, the Port Authority could determine the size of the Safety Zone for each type of LNG bunkering operation.

The following Table 8.3 provides the necessary guidance on the technical and safety attributes a LNG Bunker Truck, LNG Bunkering Barge / Vessel and Fixed LNG Storage Tanks should comply with in order to qualify to operate in the safety zone, including requirements set in prescriptive regulations.

The table contains details of each bunkering mode in separate columns, then for each mode, gives details of their technical features and form factor in the rows. The information in the rows represents "one scenario" for arriving at the safe distance, meaning if some of the characteristics change (e.g. less gas detectors, no ESD, etc.) the calculations will need to be redone for the new assumptions – the act of doing multiple iterative calculations is called a parametric analysis or sensitivity analysis.

The preliminary values for safety zones distances, resulting from the technical features and scenarios, are given on the last two rows of the table.

Table 8.3 Preliminary, Deterministic Safety Zone Siting Matrix: Technical and Safety Attributes for LBT, LBB, LBV & Fixed Tanks. Source: Lloyd's Register 2019

Technical and Safety Attributes	LNG Bunker Truck For TTS	LNG Bunker Barge, Vessel for STS		Fixed LNG Storage Tank for PTS	
	Pressure Vessel Tank	Type C Tank	Membrane, Prismatic type B tank	Pressure Vessel (Bullet Tank)	Flat Bottom Tank (Atmospheric Tank)
Approximate Volume	30-60 m3 each tank can utilise parallel tanks	200 – 10,000 m3	5,000 – 40,000 m3	200 – 1,000 m3	2,000 – 250,000 m3
Tank penetration	Bottom and top tank penetration. Some bottom penetration may not have an isolation valve	Bottom and top penetrations. All penetrations are fitted with an isolation valve. LNG transfer piping and vapour return piping are fitted with remote operated ESD valves.	Top Penetration only. All penetrations are fitted with an isolation valve. LNG transfer piping and vapour return piping are fitted with remote operated ESD valves	Bottom and top penetrations. All penetrations are fitted with an isolation valve. LNG transfer piping and vapour return piping are fitted with remote operated ESD valves.	Top Penetration only. All penetrations are fitted with an isolation valve. LNG transfer piping and vapour return piping are fitted with remote operated ESD valves.
LNG Transfer Equipment	Pressure build-up unit Submerged LNG pumps External LNG pump skid	Submerged LNG Pumps	Submerged LNG pumps	Submerged LNG pumps. External LNG pumps	Submerged LNG pumps. External LNG pumps
Piping System	Flexible hose	Supported flexible hose Loading Arm (fixed piping with 6 degrees of freedom)	Supported flexible hose Loading Arm (fixed piping with 6 degrees of freedom)	Supported flexible hose Loading Arm (fixed piping with 6 degrees of freedom)	Supported flexible hose Loading Arm (fixed piping with 6 degrees of freedom)

Technical and Safety Attributes	LNG Bunker Truck For TTS	LNG Bunker Barge, Vessel for STS		Fixed LNG Storage Tank for PTS	
	Pressure Vessel Tank	Type C Tank	Membrane, Prismatic type B tank	Pressure Vessel (Bullet Tank)	Flat Bottom Tank (Atmospheric Tank)
Connection, Emergency Release Coupling	Dry connection, disconnection couplings	Dry connection, disconnection couplings -Emergency release coupling	-Dry connection, disconnection couplings Emergency release coupling	Dry connection, disconnection couplings Emergency release coupling	Dry connection, disconnection couplings Emergency release coupling
Leakage Protection, Mitigation	Not applicable	Double wall philosophy at tank penetrations, Double wall LNG piping at enclosed spaces Single wall LNG piping at open deck, exposed positions. Automated emergency shutdown capability	Double wall philosophy at tank penetrations Double wall LNG piping at enclosed spaces Single wall LNG piping at open deck, exposed positions. Automated emergency shutdown capability	Applies a single integrity or double integrity tank design. Double integrity design requires in a concrete pit or dike arrangement LNG piping of single wall design. Automated emergency shutdown capability	Applies a double integrity or full integrity tank design. Full integrity design results in a full gas tight secondary barrier. LNG piping of single wall design. Automated emergency shutdown capability
Emergency shutdown, isolation	Relies on manual shutdown initiation and coordination	Pre-determined shutdown and isolation scenarios Automated response and software coordinated actions (i.e. ESD logic) between bunker vessel and receiving ship.	-Pre-determined shutdown and isolation scenarios Automated response and software coordinated actions (i.e. ESD logic) between bunker vessel and receiving ship.	Pre-determined shutdown and isolation scenarios Automated response and software coordinated actions (i.e. ESD logic) between bunker facility and receiving ship.	Pre-determined shutdown and isolation scenarios Automated response and software coordinated actions (i.e. ESD logic) between bunker facility and receiving ship.
Operating pressure, Transfer flow rate	Up to 9 bar-g 50-250 m3/hr	Up to 9 bar-g 200 – 1,000 m3/hr	Up to 9 bar-g 2,000 – 5,000 m3/hr	Up to 18 bar-g 200 – 1,000 m3/hr	Up to 18 bar-g 2,000 – 5,000 m3/hr

Technical and Safety Attributes	LNG Bunker Truck For TTS	LNG Bunker Barge, Vessel for STS		Fixed LNG Storage Tank for PTS	
	Pressure Vessel Tank	**Type C Tank**	**Membrane, Prismatic type B tank**	**Pressure Vessel (Bullet Tank)**	**Flat Bottom Tank (Atmospheric Tank)**
Worst Credible Leakage	Damage of tank bottom pipe penetration without an isolation valve. Loss of containment event	-Damage of hose from dropped object. -Rupture of faulty hose.	-Damage of hose from dropped object. -Rupture of faulty hose.	-Leakage from bottom tank penetration i.e. instrumentation may have a manual isolation valve rather than a remote operated ESD	-Loading arm ESD 2 initiation. Trapped volume between two ends of a powered emergency release coupling. Measured in a few litres. -Dropped object on loading arm will have limited LNG pipe damage given its rigid construction.
Leakage duration	Hours. Dictated by the initial working transfer pressure followed by pressure decay from depressurisation of the tank	Minutes. Automatic initiation of ESD 1 from 60% LFL gas detection. Manual initiation of ESD1 from receiving ship or bunker facility	Minutes. Automatic initiation of ESD 1 from 60% LFL gas detection. Manual initiation of ESD1 from receiving ship or bunker facility	Hours. Dictated by the saturated pressure/temperature conditions in the tank followed by pressure decay	Few seconds. Minute volume released from ERC activation
Approximate distance to LFL (baseline)	50m radius from truck cold box ISO 20519 Annex B Figure B.4	25m radius from either side of the flexible hose system as per ISO 20519 Annex B Figure B.3	40m radius from either side of the flexible hose system as per ISO 20519 Annex B Figure B.3	20m radius from the tank penetrations (cold box enclosure) as per ISO 20519 Annex B Figure B.4	20m radius from ERC (emergency release coupling) of the loading arm as per ISO 20519 Annex B Figure B.3
Deterministic Safety Zone Distance **(20% margin on top of LFL distance)**	60m radius, based on initial 5 bar-g working tank pressure.	30m radius based on near instantaneous release of 0.133m3 of LNG (i.e. 30m of 75mm diameter) following a hose rupture	50m radius based on near instantaneous release of 0.37m3 of LNG (i.e. 30m of 125mm diameter) following a hose rupture	25m radius, based on near ambient pressure, (i.e. close to 1 bar-g) saturated conditions in the tank	25m radius based on the design volumetric release from ERC.
Basic Safety Distance Parametric, Sensitivity Analysis	-If LNG pumps are fitted and the tank is kept at saturated pressure	-The release volume and thus the safety distance are strongly	-The release volume and thus the safety distance are strongly	-Consider: damage of fixed LNG piping from the storage tank to the LNG manifold facing the harbour. Using 100m	-Consider the fixed LNG piping leakage scenario. Assuming a 100m length and

Technical and Safety Attributes	LNG Bunker Truck For TTS	LNG Bunker Barge, Vessel for STS		Fixed LNG Storage Tank for PTS	
	Pressure Vessel Tank	Type C Tank	Membrane, Prismatic type B tank	Pressure Vessel (Bullet Tank)	Flat Bottom Tank (Atmospheric Tank)
	condition, safety zone can be reduced to 25m. -Remotely operated valves should reduce safety zone radius to 35m. -If bunkering location is sloping, or there are persistent wind conditions – the safety distance should be larger and the value derived using integral and/or CFD modelling	influenced by the size and length of the flexible hose arrangement. -Geographical features (sloping position) and average weather conditions (wind strength, direction) strongly influence the safety distance.	influenced by the size and length of the flexible hose arrangement. -Geographical features (sloping position) and average weather conditions (wind strength, direction) strongly influence the safety distance.	length and 100mm diameter pipe, fitted with ESD valves positioned at the tank and the manifold end and LNG volume of 0.8m3. Since piping rarely ruptures, a growing crack represented by a 25mm hole size is used at 5 bar-g working pressure. This results in a distance of 50m to LFL as per ISO 20519 Annex B Figure B.4 and a safety distance of 60m.	150mm diameter pipe containing 1.77m3 of LNG. Since piping rarely ruptures, a growing crack represented by a 25mm hole size is used at 5 bar-g working pressure. This results in a distance of 50m to LFL as per ISO 20519 Annex B Figure B.4 and a safety distance of 60m.

Recommended Safety Zone:

Provided all the conditions set on Table 8.3 are met, the Port Authority can preliminarily consider areas for LNG Bunkering operation within the Port where they can apply Safety Zone distances/ radius as indicated on bottom row on the table, and as shown again below, for ease of reference.

The Port Authority can designate areas within their facilities where safe LNG bunkering operations could preliminarily be considered, provided the area is of the size shown in Table 8.3 and in below Table 8.4 for easy reference, provided the requirements set in Table 8.3 are observed within such areas.

Table 8.4 Preliminary safety zone distances derived from a deterministic approach; Source: Lloyd's Register 2020

Preliminary Safety Zone Distance in metres: derived from a Deterministic approach					
Transfer Method	**TTS**	**STS**	**STS**	**PTS**	**PTS**
LNG tank type		Type C	Membrane / Prismatic	Pressure Vessel	Flat bottom (atmospheric)
Preliminary distance	60 m radius	30 m radius	50 m radius	25 m radius	25m radius

At this point the Port would have established where the area for LNG bunkering operation is, and what the required safety zone size is. The next phase in planning would require undertaking a series of risk assessments commensurate with what each BFO would provide.

8.3.1. LNG Bunkering at Anchorage

It is becoming more and more common that LNG Bunkering is performed STS while both the RSO and the LBV/LBB are side to side at a controlled anchorage location.

In this case, STS LNG Bunkering operation requirements apply. The safety zone can be established by aligning with the requirements for safety zones, including distances, for when STS is performed on a RVs whilst alongside a terminal but, additionally, for the case at an anchorage, it would be recommended that:

- Approved STS LNG Bunkering operations are allowed to be performed on protected waters, and
- Weather conditions are considered equivalent to the conditions of the RSO when alongside the terminal quay
- Or, otherwise, a Maritime Traffic Risk Assessment is performed for the designated protected waters anchorage area where LNG bunkering is intended to be performed by STS transfer method. The required measures from the analysis are to be included in the approved LNG bunkering procedures at anchorage.

Annex 1 LNG custody transfer report

The following describes what the desired reporting requirements are when concluding the LNG custody transfer. LNG custody transfer reports should be adapted considering the supply mode and additional considerations i.e (Gas Transport System Operators available measurements)

General information

Name of the bunker tanker + IMO number
Date
Loading/unloading terminal and port
Country (origin and destination)
Beginning of loading/unloading and end of loading/unloading
Reference number

Basic data

Custody transfer data before and after loading/unloading:
Level measurements in each bunker tanker
Temperatures of transferred LNG and displaced gas
Trim, list and thermal corrections in each cargo tank
Volume in each cargo tank
Mean temperature of the LNG.
Mean temperature of the displaced gas
Summed LNG volume of all cargo tanks before and after loading/unloading
Certificate of loading/unloading:
Total LNG volume loaded/unloaded
Cargo tanks pressure and corresponding mean pressure
Port log
Notice of readiness
Information on sampling operations
Number of samples drawn during transfer operations

Custody transfer data

Net loaded/unloaded LNG volume (m^3)
Net loaded/unloaded LNG mass (tonne)
Mean composition of LNG (mol %)
Molecular weight of LNG (kg/kmol)
Pseudo-molar volume (m^3/kmol)
Corrected molar volume (m^3/kmol)
Loaded/unloaded LNG density (kg/m3)
Gas density (kg/m^3) at specified conditions
Mass gross calorific value (MJ/kg)
Volume gross calorific value (MJ/m3(n))
Wobbe Index (MJ/m3(n))
Expansion ratio (m3(s)gas/m3LNG)
Loaded/unloaded energy quantity (GJ)
Vapour return energy quantity (MJ)
Any gas to engine room energy quantity (MJ)
LNG vessel energy consumption during transfer operations (MJ)
Net loaded/unloaded energy quantity (GJ)