SEAterminals

Autorità Portuale di Livorno

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# SEATERMINALS Project

## Activity 1: Assessment, Engineering and Prototyping

# Technical assessment on LNG logistics development in Port of Livorno – North Tyrrhenian area based on cryogenic ISO tank containers utilization

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# 1. Introduction

## Objective of the Study

The main objective of the study is to define the technical assessment of the development of the LNG potentialities inside the targeted area from both maritime and intermodal logistics point of view based on cryogenic ISO tank container utilization.

## Rationale of the study

LNG becomes cheaper and attractive only if the costs for the final stage of the supply chain are contained since the price at the plant depends basically on the world LNG market.
This objective can be reached whenever an efficient LNG supply from the import terminal at the port is achieved, ensuring a delivery service by bunker barge and whenever it will be possible to implement a low-cost distribution of LNG to other ports and land consumption basins that insist on the territory of reference that can be cost-effectively implemented.

Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 refers to the deployment of alternative fuels infrastructure, stating in particular:
"LNG is an attractive fuel alternative for vessels to meet the requirements for decreasing the Sulphur content in marine fuels in the SOx Emission Control Areas which affect half of the ships sailing in European short sea shipping, as provided for by Directive 2012/33/EU of the European Parliament and of the Council (1). A core network of refueling points for LNG at maritime and inland ports should be available at least by the end of 2025 and 2030, respectively. Refueling points for LNG include, inter alia, LNG terminals, tanks, mobile containers, bunker vessels and barges. The initial focus on the core network should not rule out the possibility of LNG also being made available in the longer term at ports outside the core network, in particular those ports that are important for vessels not engaged in transport operations. The decision on the location of the LNG refueling points at ports should be based on a cost-benefit analysis including an examination of the environmental benefits. Applicable safety-related provisions should also be taken into account. The deployment of LNG infrastructure provided for in this Directive should not hamper the development of other potentially upcoming energy-efficient alternative fuels.
Member States should ensure an appropriate distribution system between storage stations and refueling points for LNG. As regards road transport, the availability and geographical location of loading points for LNG tank vehicles are essential to developing an economically sustainable LNG mobility".

The adoption of ISO Cryo-containers represents an effective way to enhance the competitiveness of the whole chain, and the present study investigates all the issues related to the use of such a technology.
LNG, including liquefied biomethane, might also offer a cost-efficient technology allowing heavy-duty vehicles to meet the stringent pollutant emission limits of Euro VI standards as referred to in Regulation (EC) No 595/2009 of the European Parliament and of the Council (3).

## Environmental drivers

LNG as fuel reduces air emissions (by 10-20% $CO_2$, by 80-90% $NO_x$, almost zero PM & $SO_x$) Further $CO_2$ reduction is possible by "blending" (balance) with BIO-LNG.

### Economical drivers

Most relevant economical drivers are the following:

- price gap between diesel fuel and LNG;
- estimated price reduction for LNG due to massive production increase;
- favorable payback time of investment;
- significant reduction in fuel consumption; fuel cost savings result into higher profitability/lower transport costs.

LNG will increase transport volumes and will offer energy cost savings to many transport sectors, thus reducing oil dependency and supporting diversification of energy mix.
Logistics will play a great role in decreasing the final LNG fuel cost and the cryogenic ISO tank container could supply a significant contribution.

### Proposal for a " Livorno LNG Logistic system (L3)"

The development of an Lng logistic system in the Livorno area is strictly related to the strategic presence of OLT platform, at short distance (12 nautical miles) from the port, and is based on three nodes:

- **NODE 1 : FSRU - Floating Storage Regasification Unit**, developed by OLT - Offshore LNG Toscana S.p.A. (hereinafter OLT). OLT is one of the most important projects of national interest for the energy sector, its importance being related to the following considerations:
  - the maximum authorized capacity is 3,75 billion m3/year which represents 4% of the national requirements;
    the connection to the mainland is ensured by a pipeline of about 30 km, which is part of the national network of gas pipelines of Snam Rete Gas (hereinafter SRG);
  - the project followed a complex authorization procedure under article 8 of Law 340/00, ending with the advice and consent in favor of all institutions and stakeholders, both locally and nationally (Decree of the Ministry Economic Development of 23 February 2006);
  - with regard to the gas pipeline, OLT handed over to SRG all permits relating to its establishment and operation for both sea and land;
  - at the moment the platform is not equipped for a direct LNG transfer to LNG bunker barges, but the modification is under study as part of the SeaTerminal project;
- **NODE 2 : LNG Terminal in the Port of Livorno**, capable of serving the port area; the purpose is to feed LNG powered ships, other LNG bunker shuttle barges, and also land vehicles. Barges can be used for the supply of LNG powered ships (in the port or in other ports) or for the supply of island distribution networks (i.e.: Sardinia);
- **NODE 3 : LNG/CNG land distribution station** to be located in an area easily accessible by road, for land service (trucks and cars).

### Outcome of the study

The study will consider the connection of the 3 nodes. In order to ensure a competitive logistics between the nodes. a comparison between the traditional means of transport (LNG bunker barges or LNG tank trucks) and the alternative of the ISO Cryo-containers technology, used both on board and on land.

## 2. Cryogenic containers characteristics.

Containerization is an operation of storage of goods in containers structured according to ISO standards. This process has allowed a significant reduction of time and cost of cargo handling, creating the conditions for a consistent increase in world trade.
The distribution chain has been simplified, the product remains safely stored in the container from departure at the manufacturer's plant to delivery to the end customer.
The container can be moved in an automated and standardized manner with specific handling equipment tested over the time and widespread all over the world.

### 2.1 General characteristics

LNG is a gas that for being liquefied requires to be kept at extremely low temperatures (below -161 degrees Celsius) and in case of transfers or manipulation presents relevant phenomena of evaporation (boiling off - BOG) and risk of fire. The use of containers (Cryo-containers) reduces significantly the direct handling of the dangerous goods and subsequently the risks that involves LNG transfer and liquid pouring off.

From the economical point of view it is important to stress that LNG distribution, storage infrastructure and logistics are key factors for the competitiveness of this fuel.
Containerization entails a significant reduction in transport costs due to the widespread availability of a worldwide basic transport chain already into operation completely dedicated to the management of containers (vessels, barges, tractors and chassis, specialized container terminals, etc.). Therefore, it can be stated that Containerized LNG circumvents the distribution issue by using existing and widespread container handling equipment.

From the logistics point of view, Cryo-Container means a quickly implementable LNG distribution system "without borders" especially for maritime transport and furthermore the Cryo-Container presents an effective economy of scale since no matter how small the service target is (Ports, Inland Road, Rail LNG Stations or Isolated gas networks), the Containerized LNG allows the start up of any new facility by bringing in LNG in a few weeks with low profile investments.

From the sea-transport point of view, a Containership can use any port facility capable of handling Containers (Terminals, deposits, etc.). where it is possible to allocate an area dedicated to Cryo-containers. In this case it is not necessary to provide for direct handling of LNG to coastal deposits because each container is a supply of LNG that can be uploaded/downloaded individually or in groups to other points of service at land (or on-board ships) for transport to remote areas, and can be placed in special spaces to dispense LNG to local users.
The Cryo-container can even deliver LNG to the final user for direct consumption, or deliver "one" or "n" containers on a container feeder ship to feed far destinations (I.e.: Sardinia network terminal).

This was the strategy already adopted in Northern America, for supplying LNG to isolated markets in the Caribbean and Gulf of Mexico. Particularly significant is the example of Hawaii islands, where long waiting times were avoided by obtaining the green light by local authorities, and LNG supply was almost immediately set into operation to fit demand.

### 2.2 Technical characteristics

This paragraph reports the most relevant characteristics of a Cryo-container.

Construction:

- Stainless/Nickel steel inner tank
- Vacuum interstitial space
- Carbon steel outer tank
- Type C tank compliancy to allow use onboard as shipboard fuel bunker
- Dry break-away coupling to prevent LNG spills in case of accidental removal from the container stack

ISO IMDG general specifications:

- IMDG, TPED, ADR, RID, IMO Type-C and ISO frame compliancy
- Size: 20 ft. or 40 ft.
- Capacity: from 16000 to 45000 liters
- Pressure range: from 4 to 25 barg
- Design temperature: -196 °C
- Maximum gross weight: 34.000 kg
- Insulation: Multi-layer super insulation under vacuum
- Material used: Outer jacket in carbon steel and inner vessel in stainless steel
- Outer finishing: white paint
- Piping arrangement: all stainless steel pipework
- Well insulated to ensure long holding time (Hold time - 60 to 110 days)
- Equipments:
  - safety relief devices for both outer and inner vessel
  - heat exchanger vaporizer,
  - pressure control regulator,
  - pressure / temperature sensor,
  - gas detector,
  - check valve, pressure relief valve, excess flow valve, manual valve and non-return valve,
  - leakage detection and protection,
  - dry disconnect quick couplings

Uses and Applications

- Relatively organized supply chains
- LNG Temporary storage
- Sea, Rail and truck transport, fully intermodal

# 3. Applicable regulations

Cryo-containers must be compliant with a wide set of regulations, related to different aspects and to specific uses foreseen for the container; the following chapters give an overview of existing regulations, as well as incoming proposals of new regulations.

## 3.1 Transportation regulations

### 3.1.1 Directive 2010/35/EU - TPED - Transportable Pressure Equipment Directive.

TPED is the Directive 2010/35/EU of the European Parliament and of the Council of 16 June 2010 on transportable pressure equipment, repealing Council Directives 76/767/EEC, 84/525/EEC, 84/526/EEC, 84/527/EEC and 1999/36/EC (Text with EEA relevance)
TPED updates previous technical provisions of Directive 1999/36/EC to avoid conflicting rules. It sets out detailed rules on transportable pressure equipment (all pressure receptacles, their valves and other accessories like tanks, battery vehicles/wagons, multiple-element gas containers, gas cartridges, open cryogenic receptacles, gas cylinders for breathing apparatus and fire extinguishers) to improve safety and to ensure free movement of such equipment within the European Union.

In particular TPED applies to:

- new transportable pressure equipments which do not bear the conformity markings provided for in Directives 84/525/EEC,84/526/EEC, 84/527/EEC or 1999/36/EC, for the purpose of making it available on the market;
- transportable pressure equipment bearing the conformity markings provided for in the above directives, for the purposes of its periodic inspections, intermediate inspections, exceptional checks and use;
- transportable pressure equipment which does not bear the conformity markings provided for in Directive 1999/36/EC, for the purposes of reassessment of conformity.

Specific obligations to economic operators, acting in commercial or public service activity, both regularly paid and free of charge, derive from the application of TPED:

- Manufacturers must ensure that when placing their transportable pressure equipment on the market, the equipment has been designed, manufactured and documented in compliance with the requirements in both this directive and in Directive 2008/68/EC. When this compliance is demonstrated through the conformity assessment process, manufacturers must affix the “Pi marking” (marking which indicates that the transportable pressure equipment is in conformity with the applicable conformity assessment requirements set out in Directive 2008/68/EC) to the equipment. This Pi marking must only be affixed by the manufacturer or, in cases of reassessment of conformity, by or under the surveillance of the notified body.
- Manufacturers may, by a written mandate, appoint an authorized representative. The mandate will specify tasks for the authorized representative to undertake, but will include: keep the technical documentation at the disposal of national surveillance authorities; provide the competent national authority, on request, with all necessary information and documentation to prove the conformity of the transportable pressure equipment; cooperate with the competent national authorities on action taken to eliminate any risks posed by the equipment covered by the mandate.
- Importers and distributors may only place on the EU market transportable pressure equipment that complies with Directive 2008/68/EC and this directive. They must ensure that the equipment bears the Pi marking and has the necessary certificate of conformity.

- Importers, distributors and owners must inform the manufacturer and competent authority of any risk presented by the equipment. Alternatively, where relevant, the distributor shall inform the importer and the owner shall inform either the distributor or the importer of such a risk; document all instances of non-compliance and corrective measures; ensure that when transportable pressure equipment is under their responsibility.

The transportable pressure equipment must meet the relevant conformity assessment, periodic inspection, intermediate inspection and exceptional checks requirements, as well as the specifications of the documentation according to which the equipment was manufactured.
No EU country may prohibit, restrict or impede the free movement, the placing on the market and the use of transportable pressure equipment on their territory, when the above complies with this directive.

### 3.1.2 Directive 2008/68/EC - Inland transport of dangerous goods

“Directive 2008/68/EC of the European Parliament and of the Council (24 September 2008) on the inland transport of dangerous goods” establishes a common regime for all aspects of the inland transport of dangerous goods, by road, rail and inland waterways within any European Union (EU) country or between EU countries.
The international transport of dangerous goods is regulated by international agreements: ADR, RID and ADN. Such rules should also be extended to national transport in order to harmonize across the EU the conditions under which dangerous goods are transported and to ensure the proper functioning of the common transport market. The annexes of the directive ~~e~~ refer to the texts of these agreements.
ADR, RID and ADN have drawn up a list of dangerous goods, indicating whether their transport is prohibited or not and defining the requirements for their transport if it is authorized. EU countries may request temporary derogations under certain conditions.

#### 3.1.2.1 ADR: International Carriage of Dangerous goods by Road

The European Agreement concerning the international Carriage of Dangerous Goods by Road (ADR) was done at Geneva in 1957 under the auspices of the United Nation Economic Commission for Europe (UNECE) and entered into force on 29 January 1968. The Agreement itself was amended by the Protocol amending article 14 (3) signed in New York on 21 August 1975, which entered into force on 19 April 1985.
The agreement is made up of two annexes, Annex A and Annex B, each one divided into nine parts.
Annexes A and B have been regularly amended and updated since the entry into force of ADR.
Consequently, for entry into force on 1 January 2015, a revised consolidated version has been published as document ECE/TRANS/242, Vol. I and II ("ADR 2015").

**Annex A**: General provisions and provisions concerning dangerous articles and substances:

- Part 1 - general provisions
- Part 2 - classification
- Part 3 - dangerous goods list, special provisions and exemptions related to limited and excepted quantities
- Part 4 - packing and tank provisions
- Part 5 - consignment procedures
- Part 6 - requirements for the construction and testing of packaging, intermediate bulk containers (IBCs), large packaging, tank and bulk containers
- Part 7 - provisions concerning the conditions of carriage, loading, unloading and handling).

**Annex B**: Provisions concerning transport equipment and transport operations

- Part 8 - requirements for vehicle crews, equipment, operation and documentation
- Part 9 - requirements concerning the construction and approval of vehicles.

Part 1 is an essential part because it contains all definitions for terms and defines the scope and applicability of ADR, contains provisions concerning training, derogations and transitional measures, safety obligations of the participants in a chain of transport of dangerous goods, derogations, control measures, transport restrictions by the competent authorities, etc…security provisions, etc…
The following table contains the dangerous goods list in numerical order of UN numbers, name and description, class, packing group, labels, special provisions, limited and excepted quantities, packaging and portable tanks and bulk containers, etc.

| UN No. | Name and description | Class | Classification code | Packing group | Labels | Special provisions | Limited and excepted quantities | | Packaging | | | Portable tanks and bulk containers | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Packing instructions | Special packing provisions | Mixed packing provisions | Instructions | Special provisions |
| | 3.1.2 | 2.2 | 2.2 | 2.1.1.3 | 5.2.2 | 3.3 | 3.4 | 3.5.1.2 | 4.1.4 | 4.1.4 | 4.1.10 | 4.2.5.2 | 4.2.5.3 |
| (1) | (2) | (3a) | (3b) | (4) | (5) | (6) | (7a) | (7b) | (8) | (9a) | (9b) | (10) | (11) |
| 1972 | METHANE, REFRIGERATED LIQUID or NATURAL GAS, REFRIGERATED LIQUID with high methane content | 2 | 3F | | 2.1 | 660 | 0 | E0 | P203 | | MP9 | T75 | TP5 |

| ADR tank | | Vehicle for tank carriage | Transport category (Tunnel restriction code) | Special provisions for carriage | | | | Hazard identification No. | UN No. | Name and description |
|---|---|---|---|---|---|---|---|---|---|---|
| Tank code | Special provisions | | | Packages | Bulk | Loading, unloading and handling | Operation | | | |
| 4.3 | 4.3.5, 6.8.4 | 9.1.1.2 | 1.1.3.6 | 7.2.4 | 7.3.3 | 7.5.11 | 8.5 | 5.3.2.3 | | 3.1.2 |
| (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (1) | (2) |
| RxBN | TU18 TA4 TT9 | FL | 2 (B/D) | V5 | | CV9 CV11 CV36 | S2 S17 | 223 | 1972 | METHANE, REFRIGERATED LIQUID or NATURAL GAS, REFRIGERATED LIQUID with high methane content |

### 3.1.2.2 RID: International Carriage of Dangerous Goods by Rail

The Intergovernmental Organization for International Carriage by Rail (OTIF) was set up on 1 May 1985 and the Organization's basis under international law is the Convention of 9 May 1980, COTIF, Convention concerning International Carriage by Rail, that is currently applied in Europe, in Maghreb and in the Middle East.
The predecessor of OTIF was the Central Office for International Carriage by Rail, which was set up in 1893.
Until the signature of the Protocol of 3 June 1999 (Vilnius Protocol) for the modification of COTIF, the objective of this Governmental Organization was principally to develop the uniform systems of law which apply to the carriage of passengers and freight in international through-traffic by rail. These systems of law have been in existence for decades and are known as the CIV and CIM Uniform Rules.
OTIF Member States apply the majority of the appendices to COTIF:

- CIV, Uniform Rules concerning the Contract of International Carriage of Passengers by Rail, Appendix A to COTIF;

- CIM, Uniform Rules concerning the Contract of International Carriage of Goods by Rail; Appendix B to COTIF;
- RID, Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) – Appendix C to COTIF;
- CUV, Uniform Rules concerning Contracts of Use of Vehicles in International Rail Traffic (CUV) - Appendix D to COTIF;
- CUI, Uniform Rules concerning the Contract of Use of Infrastructure in International Rail Traffic (CUI) - Appendix E to COTIF;
- APTU, Uniform Rules concerning the Validation of Technical Standards and the Adoption of Uniform Technical Prescriptions applicable to Railway Material intended to be used in International Traffic (APTU) - Appendix F to COTIF;
- ATMF Uniform Rules concerning the Technical Admission of Railway Material used in International Traffic (ATMF) - Appendix G to COTIF.

RID regulation consists of the following parts:

- Part 1 - General requirements
- Part 2 - Classifications
- Part 3 - Dangerous good list, special provisions and exemptions related to limited and excepted quantities (see example in the following table)
- Part 4 – Packing and tank provisions
- Part 5 - Consignment procedures
- Part 6 - Requirements for the construction and testing of packaging, intermediate bulk containers (IBCs), large packaging and tanks
- Part 7 - Provisions concerning the conditions of carriage, loading, unloading and handling.

| UN No. | Name and description | Class | Classifi-cation code | Packing group | Labels | Special provi-sions | Limited and excepted quantities | | Packaging | | | Portable tanks and bulk containers | | RID Tanks | | Transport category | Special provisions for carriage | | | Colis express (express parcels) | Hazard identifi-cation No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Packing instructions | Special packing provisions | Mixed packing provi-sions | Instruc-tions | Special provi-sions | Tank code | Special provi-sions | | Packages | Bulk | Loading, unloading and handling | | |
| | 3.1.2 | 2.2 | 2.2 | 2.1.1.3 | 5.2.2 | 3.3 | 3.4/3.5.1.2 | | 4.1.4 | 4.1.4 | 4.1.10 | 4.2.5.2, 7.3.2 | 4.2.5.3 | 4.3 | 4.3.5, 6.8.4 | 1.1.3.1c) | 7.2.4 | 7.3.3 | 7.5.11 | 7.6 | 5.3.2.3 |
| (1) | (2) | (3a) | (3b) | (4) | (5) | (6) | (7a) | (7b) | (8) | (9a) | (9b) | (10) | (11) | (12) | (13) | (15) | (16) | (17) | (18) | (19) | (20) |
| 1972 | METHANE, REFRIGERATED LIQUID or NATURAL GAS, REFRIGERATED LIQUID with high methane content | 2 | 3F | | 2.1 (+13) | 660 | 0 | E0 | P203 | | MP9 | T75 | TP5 | RxBN | TU18 TU38 TE22 TA4 TT9 TM6 | 2 | W5 | | CW9 CW11 CW30 CW36 | CE2 | 223 |

### 3.1.2.3 ADN: International Carriage of Dangerous Goods by Inland Waterways

The European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN) was done at Geneva on 26 May 2000 on the occasion of a Diplomatic Conference held under the joint auspices of the United Nations Economic Commission for Europe (UNECE) and the Central Commission for the Navigation of the Rhine (CCNR). It entered into force on 29 February 2008.
ADN consists of a main legal text (the Agreement itself) and annexed Regulations and aims at:

- ensuring a high level of safety of international carriage of dangerous goods by inland waterways;
- contributing effectively to the protection of the environment by preventing any pollution resulting from accidents during such carriage;
- facilitating transport operations and promoting international trade in dangerous goods.

The Regulations annexed to ADN contain provisions concerning dangerous substances and articles,

provisions concerning their carriage in packages and in bulk on board inland navigation vessels or tank vessels, as well as provisions concerning the construction and operation of such vessels.
They also address requirements and procedures for inspections, the issue of certificates of approval, recognition of classification societies, monitoring, and training and examination of experts.

ADN regulation consists of the following parts:

- Part 1: General provisions
- Part 2: Classification
- Part 3: Dangerous goods list, special provisions and exemptions related to dangerous goods packed in limited quantities
- Part 4: Provisions concerning the use of packaging, tanks and bulk transport units
- Part 5: Consignment procedures
- Part 6: Requirements for the construction and testing of packaging (including IBCs and large packaging), tanks and bulk transport units
- Part 7: Requirements concerning loading, carriage, unloading and handling of cargo
- Part 8: Provisions for vessel crews, equipment, operation and documentation
- Part 9: Rules for construction

### 3.1.3 CSC - The International Convention for Safe Containers 1972

The International Convention for Safe Containers 1972 is a regulation by the Inter-governmental Maritime Consultative Organization, IMO, on the safe handling and transport of containers. It states that every container travelling internationally be fitted with a CSC Safety-approval Plate. This holds essential information about the container, including age, registration number, dimensions and weights, as well as its strength and maximum stacking capability.
In the 1960s, there was a rapid increase in the use of freight containers for the consignment of goods by sea and the development of specialized container ships. In 1967, IMO undertook to study the safety of containerization in marine transport. The container itself emerged as the most important aspect to be considered.
IMO, in cooperation with the Economic Commission for Europe, developed a draft convention and in 1972 the finalized Convention was adopted at a conference jointly convened by the United Nations and IMO.
CSC has two goals:

- to maintain a high level of safety of human life in the transport and handling of containers by providing acceptable test procedures and related strength requirements;
- to provide uniform international safety regulations, equally applicable to all modes of surface transport, thereby avoiding the proliferation of divergent national regulations.

The Convention includes two Annexes:

- Annex I includes Regulations for the testing, inspection, approval and maintenance of containers
- Annex II covers structural safety requirements and tests, including details of test procedures.

Annex I sets out procedures whereby containers used in international transport must be safety-approved by an Administration of a Contracting State or by an organization acting on its behalf.
The Administration or its authorized representative will authorize the manufacturer to affix to approved containers a safety approval plate, containing the relevant technical data, which should be recognized by other Contracting States. This principle of reciprocal acceptance of safety-approved containers is the

cornerstone of the Convention; as a consequence it is expected that containers will move in international transport with the minimum of safety control formalities.

The amendments to CSC 1972 adopted by resolution MSC.355(92) entered into force on 1 July 2014 and include:

• new definitions at the beginning of annexes I and II, along with consequential amendments to ensure uniform usage of terminology throughout CSC 1972;

• amendments to align all physical dimensions and units to the SI system;

• the introduction of a transitional period for marking containers with restricted stacking capacity, as required under the relevant standard;

• the inclusion in annex III of the list of deficiencies which do not require an immediate out-of-service decision by the control officer but do require additional safety measures to enable safe ongoing transport.

### 3.1.4 IMDG - international agreement for the carriage by sea of dangerous goods

In case of intermodal transport the general rule says that transport must observe the more restrictive regulation and IMDG Code (international agreement for the carriage by sea of dangerous goods) is the most restrictive agreement. For example, in the case of combined land-sea transport, the IMDG will be applied, so that also the road transport will be covered. There are, however, exceptions to this rule.

The key objectives of IMDG are:

- to protect human life - crew members
- to prevent marine pollution
- to facilitate the free movement of dangerous goods.

The IMDG Code's requirements apply to all ships which are subject to the following two conventions:

- International Convention for the Safety of Life at Sea, 1974 (SOLAS 1974) – which covers the safety implications of dangerous goods onboard ships
- International Convention for the Prevention of Pollution from Ships (MARPOL) – which covers the pollution aspects for ships carrying dangerous goods

The correct edition to the IMDG Code is the 2012 Edition, incorporating Amendment 36-12. This edition was applied on a voluntary basis starting 1 January 2013 and became mandatory on 1 January 2014. The 2014 Edition, incorporating Amendment 37-14, will be voluntary on 1 January 2015 and will become mandatory on 1 January 2016.

The IMDG is updated, by the DSC Sub-Committee of the International Maritime Organization, every two years to reflect biennial revisions in the UN Recommendations on the Transport of Dangerous Goods (UN Model Regulations).

These changes reflect:

- the inclusion of newly classified dangerous substances/articles, amendments to or deletions of existing entries;
- new technologies and new methods of handling dangerous goods;
- safety concerns which arise as a result of human experience;
- new materials and designs for packaging.

IMDG consists of the following parts:

- **Volume 1**:
  - Part 1: general provisions, definitions and training
  - Part 2: classification

- Part 4: packing and tank provisions
- Part 5: consignment procedures
- Part 6: construction and testing of packaging, IBCs, large packaging, portable tanks, MEGCs and road tank vehicles
- Part 7: requirements Concerning transport operations

- **Volume 2**:
  - Part 3 Dangerous Goods List, DGL, special provisions and exceptions
  - Appendices A and B (generic and N.O.S. Proper Shipping Names, and glossary of terms).

In particular, the Dangerous Goods List is an index of substances and articles, arranged in UN Number order. It comprises 18 columns of information for each listed substance/article, presented as a two page spread in the printed books. Decisions on packing arrangements, marking and labeling requirements, documentation entries, stowage, segregation and other shipping and transport duties generally stem from the columns of the DGL.

The ADR and ADN Agreements, Appendix RID and the most restrictive IMDG code provide, in their Part 3, Dangerous Good List, DGL, which is produced both from a numerical order, and in alphabetical order.

For transport purposes, dangerous goods are allocated to one of nine 'classes', some of them further sub-divided, according to the main danger they present:

1 - Explosives
2 - Gases *(LNG- UN1972 for example)*
3 - Flammable liquids
4 - Flammable solids and other flammable substances
5 - Oxidizing substances and organic peroxides
6 - Toxic and infectious substances
7 - Radioactive material
8 - Corrosive substances
9 - Miscellaneous dangerous substances and articles


### 3.1.5 HNS Hazardous and Noxius Substances by Sea Convention

HNS (Hazardous and Noxious Substances by Sea Convention) is an international convention created in 1996 to compensate for damages caused by spillage of hazardous and noxious substances during maritime transportation. The convention is officially known as the International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, 1996. The convention has not entered into force due to signatory States not meeting the ratification requirements.

### 3.1.6 ISO 12991 for LNG transport regulation.

The International Organization for Standardization, ISO, founded on 23 February 1947, headquartered in Geneva, Switzerland, the world's largest developer of voluntary international standards and facilitates world trade by providing common standards between nations. The standards help businesses and increase productivity while minimizing errors and waste, by enabling products from different markets to be directly compared; they facilitate companies in entering new markets and assist in the development of global trade on a fair basis. The standards also serve to safeguard consumers and end-users of products and services, ensuring the conformity of certified products to minimum standards set internationally.

International Standards are developed by ISO Technical Committees (TC) and Sub Committees (SC) by a process based on six steps:

- Stage 1: Proposal stage
- Stage 2: Preparatory stage
- Stage 3: Committee stage
- Stage 4: Enquiry stage
- Stage 5: Approval stage
- Stage 6: Publication stage

The TC/SC may set up Working Groups of experts (WG) for the preparation of a working drafts. Subcommittees may have several working groups, which can have several Sub Groups, SG.
Project Committees (PC) are established when there is a need for an International Standard on a specific topic that does not fall into the scope of an existing TC.

As a result of the development of LNG, ISO is involved in LNG regulations concerning its transport, its use as a marine fuel and its use in refueling station.

ISO 12991:2012 ”Tanks for on-board storage as a fuel for automotive vehicles” was published in 2012 and it was prepared by Technical Committee ISO/TC 220, Cryogenic vessels. It specifies the construction requirements for refillable fuel tanks for liquefied natural gas used in vehicles, as well as the testing methods required to ensure that a reasonable level of protection from loss of life and property resulting from fire and explosion is provided. It is applicable to fuel tanks intended to be permanently attached to land vehicles but can be used as a guide for other modes of transport.

## 3.2 Rules for use of Cryo-containers as fuel tanks on board ships

Tanks suitable for the transport of liquid gas can be divided into five categories:

- Internal insulation tanks
- Integral tanks
- Semi-membrane tanks: very few applications
- Membrane tanks
- Independent tanks
    - Type A
    - Type B
    - Type C

According to the current IMO IGC code, International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, LNG fuel tanks must be selected from “Independent Types A, B, or C.

All LNG ships in the current fleet are fitted with a type C tank, a cylindrical pressure vessel requiring 2-4 times more space than a conventional fuel storage tank.

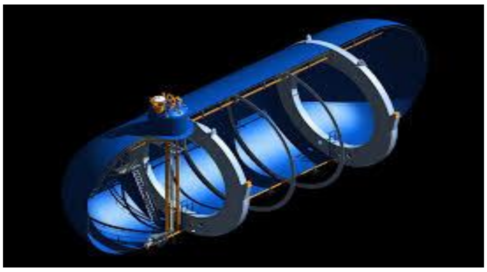
For LNG-fuelled merchant ships there are several options for installing an LNG tank.
Type C tanks are already in operation on ferries and offshore supply vessels. There are several designs for larger LNG-fuelled ships that propose using type B tanks because they require less space, but the industry is not unanimous on this issue.

Space requirements for LNG storage are greater than for conventional fuel; this may reduce cargo capacity, depending on the type of vessel, type of fuel tank and onboard potential for adequate location of the LNG tanks. Type C tanks require the most space: about 2-4 times more than an HFO, Heavy Fuel Oil, tank.
Type A and B tanks require a full or partial secondary barrier respectively to prevent potential release of the liquefied gas in the event of a tank failure. With a type C tank this risk is lower and no secondary barrier is therefore needed.

| Tank type | Description | Pressure | Pro | Con |
|---|---|---|---|---|
| **A** | Prismatic tank, adjustable to hull shape; full secondary barrier | <0.7 bar g | Space-efficient | • Boil-off gas handling.<br>• More complex fuel system required<br>• High costs |
| **B** | Prismatic tank, adjustable to hull shape; partial secondary barrier | <0.7 bar g | Space-efficient | • Boil-off gas handling.<br>• More complex fuel system required<br>• High costs |
| | Spherical tank; partial secondary barrier | | Reliably proven in LNG carriers | • Boil-off gas handling.<br>• More complex fuel system required |
| **C** | Cylindrical with dished ends, cylindrical or bilobe with outside insulation | >2 bar g | • Allows pressure increase (pressurized)<br>• Simple fuel system<br>• Little maintenance<br>• Easy installation and separate construction<br>• Lower costs<br>• Multiple cargoes<br>• No secondary barrier required<br>• Partial loading<br>• High loading/discharge rates<br>• Wide range of volume per single tank<br>• Arrangement to fit small and large terminals<br>• No restriction concerning partial filling | • Large space requie |

Although an LNG tank is properly insulated, there will be some transmission of heat from outside into the liquid, which could cause evaporation and pressure increase. Vacuum insulation or a 20-30 cm layer of polyurethane foam covered by protection sheets is applied for fuel tank insulation.
Type A and B tanks will require handling of the boil-off gas by (propulsion) engines, boilers or re-liquefaction. A 200 m3-type C tank can hold the boil-off for about 25 days before reaching the maximum allowed tank pressure.

In the next figure a detail is shown of cylindrical and bilobe constructive solutions for type C tanks:

| | |
|---|---|
| **Type C Tank – cylindrical**<br><br>Ship capacity below 15,000 m³<br>Cylindrical tank design<br>2 tank design up to abt. 10,000 m³<br>3 tank design up to abt. 15,000 m³ |  |
| **Type C Tank – bilobe**<br><br>Ship capacity above 15,000 m³<br>Bilobe tank design<br>3 tank design up to 25,000 m³<br>4 tank design up to 35,000 m³ (or even 40,000 m³) |  |

### 3.2.1 IMO IGC Code

The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) has specifically been laid down for ensuring the safety of gas carriers, including LNG.
The purpose of IGC Code is to provide an international standard to ensure the safety of gas carriers. The IGC focuses on LNG as cargo, not as fuel. The code includes prescriptions for the design and construction of the ships and onboard equipment in order to minimize the risks associated with LNG transport. This includes requirements for the materials of construction, ventilation, electric installations and fire protection.

According to the IGC Code, only LNG carriers are allowed to utilize LNG boil-off gas as fuel in the machinery space. Since 2000 few LNG-fuelled vessels, which are not covered by the IGC Code, have come into service with the permission of their national administration. This means that these vessels are only allowed to sail in national waters or need permission from each port state where the ship wants to berth and operate.

### 3.2.2 IMO IGF Code

Because the IGC Code does not cover LNG as fuel, the IMO's Marine Safety Committee has proposed the development of a code for non-LNG carriers using LNG as a fuel. This new "International Code of Safety for Ships using Gases or other Low Flashpoint Fuels" (IGF Code) is planned to come into force in 2016/2017 and is currently being prepared by IMO's Bulk and Liquid Gases (BLG) subcommittee. As the name already suggests, the IGF code covers not only LNG, but also other low-flashpoint fuels like methanol. The broad scope of this code is one of the reasons why development is taking a long time and non-agreement on other low-flashpoint fuels may hinder the overall LNG standardization process.

IGF Code will eventually replace Chapter 16 of the IGC Code, which deals with gas as fuel, and will also replace the interim guideline MSC 285 (86). The IGF Code will include requirements similar to those in the IGC Code, but also requirements for the ship's bunkering station (including the ventilation of this station) and manifold.
A main drawback of the IGF Code is that it focuses specifically on requirements for the receiving vessel, and not on the technical and operational requirements for bunkering operations.

### 3.2.3 MSC 285 (86)

Until the approval and entry into force of the IGF Code in 2016, the Interim Guideline MSC 285(86) sets criteria for LNG-fuelled machinery. With the interim guideline, IMO aims to already achieve a certain level of safety and reliability. Ships built in line with this guideline will also be allowed to operate after 2016. In this way, the industry can still continue to build LNG-fuelled vessels while the standardization process is still ongoing.
Most classification societies have developed their own guidelines based on these interim guidelines and added additional, class-specific requirements of their own.

The International Maritime Organization's Maritime Safety Committee (MSC) adopted in the new IGF Code amendments to SOLAS Chapter II-1 Part G. The Code's mandatory provisions will enter into force on 1 January 2017 and will apply to new cargo ships ≥ 500gt and passenger ships using natural gas fuel.
The IGF Code aims to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved.

The amendments to SOLAS slated to enter into force on 1 January 2017 include:

- revised cargo tank venting arrangements in SOLAS Chapter II-2 for new oil tankers constructed on/after 1 January 2017 that will require secondary means of venting to allow full flow relief of cargo or inert gas vapors at all times;
- power ventilation systems serving vehicle, special category and ro-ro spaces on new passenger and cargo ships constructed on/after 1 January 2017 are to deliver the specified number of air changes (6 or 10 air changes per hour depending on ship type and space served) at all times when vehicles are in such spaces;
- amendments of the mandatory provisions of Section 3 (Safety of personnel and ship) of the International Maritime Solid Bulk Cargoes (IMSBC) Code providing interim measures requiring the ship's crew to conduct regular on board operational fire safety risk assessments of cargo handling areas on self-unloading bulk carriers with internally installed conveyor systems;

### 3.2.4 ISO for LNG as a marine fuel

Widespread use of LNG as a marine fuel requires and infrastructure for fuel supply and internationally accepted guidelines for the bunkering process.

#### 3.2.4.1 ISO TS 18683:2015

Within the Technical Committee ISO/TC 67/SC 9 "Liquefied natural gas installations and equipment" the following standards have been developed or are under development:

Published standards:

- ISO/TS 16901:2015 "Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface";
- ISO 16903:2015 "Petroleum and natural gas industries - Characteristics of LNG, influencing the design, and material selection";
- ISO/TR 17177:2015 "Petroleum and natural gas industries - Guidelines for the marine interfaces of hybrid LNG terminals";
- **ISO/TS 18683:2015** "Guidelines for systems and installations for supply of LNG as fuel to ships";
- ISO 28460:2010 "Petroleum and natural gas industries - Installation and equipment for liquefied natural gas - Ship-to-shore interface and port operations";

Standards under development:

- ISO/AWI TR 18624 “Guidance for conception, design and testing of LNG storage tanks”;
- ISO/NP 20088-2 “Determination of the resistance to cryogenic spillage of insulation materials - Part 2: Vapor phase”;
- ISO/NP 20088-3 “Determination of the resistance to cryogenic spillage of insulation materials - Part 3: High pressure jet exposure”;
- ISO/AWI 20257 “Installation and equipment for liquefied natural gas - Design of offshore installations;

Used abbreviations: *TS – Technical Specification; TR – Technical Report; AWI – Approved new Work Item; NP – New Proposal)*

In particular, **ISO/TS 18683:2015** “Guidelines for systems and installations for supply of LNG as fuel to ships”, gives guidance on the minimum requirements for the design and operation of the LNG bunkering facility, including the interface between the LNG supply facilities and receiving ship.
It 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. ISO 18683 is 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.

### 3.2.4.2 ISO AWI 20519

Within the Technical Committee ISO/TC 8 “Ships and marine technology” the following standards have been developed or are under development:

Published standards:

- ISO 15849:2001, Ships and marine technology - Guidelines for implementation of a fleet management system network, and related AMD 1:2003;
- ISO 20858:2007, Ships and marine technology -- Maritime port facility security assessments and security plan development;
- ISO/PAS 22853:2005, Ships and marine technology - Computer applications - Specification of Maritime Safety Markup Language (MSML);
- ISO 28004-2:2014, Security management systems for the supply chain -- Guidelines for the implementation; of ISO 28000 - Part 2: Guidelines for adopting ISO 28000 for use in medium and small seaport operations;
- ISO 28005-1:2013, Security management systems for the supply chain -- Electronic port clearance (EPC) - Part 1: Message structures;
- ISO 28005-2:2011, Security management systems for the supply chain -- Electronic port clearance (EPC) - Part 2: Core data elements;
- ISO 28007-1:2015, Ships and marine technology - Guidelines for Private Maritime Security Companies (PMSC) providing privately contracted armed security personnel (PCASP) on board ships (and pro forma contract) - Part 1: General;
- ISO 29400:2015, Ships and marine technology -- Offshore wind energy -- Port and marine operations
- ISO 30000:2009, Ships and marine technology -- Ship recycling management systems -- Specifications for management systems for safe and environmentally sound ship recycling facilities;
- ISO 30002:2012, Ships and marine technology - Ship recycling management systems - Guidelines for selection of ship recyclers (and pro forma contract);

- ISO 30003:2009, Ships and marine technology - Ship recycling management systems - Requirements for bodies providing audit and certification of ship recycling management;
- ISO 30004:2012, Ships and marine technology - Ship recycling management systems - Guidelines for the implementation of ISO 30000;
- ISO 30005:2012, Ships and marine technology - Ship recycling management systems - Information control for hazardous materials in the manufacturing chain of shipbuilding and ship operations;
- ISO 30006:2010, Ship recycling management systems - Diagrams to show the location of hazardous materials onboard ships;
- ISO 30007:2010, Ships and marine technology - Measures to prevent asbestos emission and exposure during ship recycling.

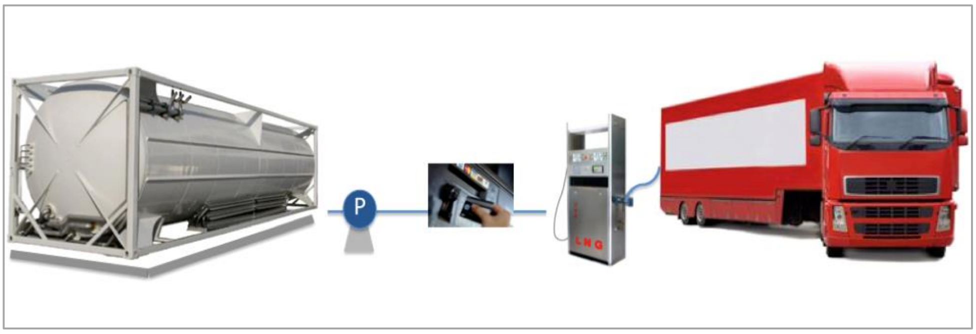
Standards under development:

- **ISO/AWI 20519**, Ships and marine technology - Vessel - LNG bunkering standard;
- ISO/AWI 20661, Cutter dredger supervisory and control system;
- ISO/AWI 20662, Hopper dredger supervisory control system,
- ISO/NP 20663, Grab dredger supervisory control system;
- ISO/PRF 29404, Ships and marine technology - Specific requirements for offshore wind farm components - Supply chain information flow;
- ISO/AWI 29406, Ships and marine technology - Offshore wind energy - Personnel transfer systems;
- ISO/CD 30003, Ships and marine technology - Ship recycling management systems -- Requirements for bodies providing audit and certification of ship recycling management;
- ISO/NP 30006, Ship recycling management systems - Diagrams to show the location of hazardous materials onboard ships;
- ISO/NP 30007, Ships and marine technology -- Measures to prevent asbestos emission and exposure during ship recycling.

In particular, **ISO/AWI 20519** "Ships and marine technology - Specification for bunkering of gas fuelled ships", developed at ISO level, will be developed in parallel at CEN level (CEN/TC 282).

## 3.3 Rules for use of Cryo-containers as LNG fuel tanks at refueling stations

LNG stations are structurally similar to gasoline and diesel stations because they both deliver a liquid fuel. LNG dispensers deliver fuel to vehicles at pressures of 30 to 120 psi.
Because LNG is stored and dispensed as a super-cooled, liquefied gas, protective clothing, face shield, and gloves are required when fueling a vehicle.




There are three options for LNG fueling: mobile containerized stations (20' or 40'), movable skidded stations and permanent full scale stations.

| | | |
|---|---|---|
| **Mobile containerized stations 20' or 40' ft.** |  | 20 or 40 m3 LNG storage. LNG is delivered by a tanker truck that has on-board metering and dispensing equipment. The station is equipped with LNG pumps, saturation of LNG, flow meter, bill printer and fueling hose with connector. |
| **Movable skidded stations** |  | 30-60 m3 LNG storage. LNG automatic saturation, automatic pump control, MID dispenser, loading with tanker pump or with own pump, container for control system and air compressor. |
| **Permanent full scale stations** |  | Full scale station with two pumps/two dispensers, cold and saturated LNG available, card-pay system, GSM distant control. |

### 3.3.1 ATEX 95 – Directive 94/9/EC

European Directive 94/9/EC of the European Parliament and the Council of 23 March 1994, better known with the French acronym ATEX (ATmosphère EXplosible), applies to all products to be used in potentially explosive environments, both surface-level plants and mines. ATEX allows the free circulation of goods within the European market and aims to eliminate – or at least reduce – the risks of an explosion of any kind which may result from the use of products as well as from their transformation process.

ATEX covers equipment and protective systems intended for use in potentially explosive atmospheres. The Directive defines the minimum technical requirements and conformity assessment procedures, to be applied before equipment is placed on the EU market.

The fourth edition of the Guidelines on the application of Directive 94/9/EC was issued in September 2012 and updated in December 2013. The new ATEX Directive 2014/34/EU on equipment and protective systems intended for use in potentially explosive atmospheres is aligned with the 'New Legislative Framework' and will be applicable from 20 April 2016. A Guidance document on the ATEX Directive transition from 94/9/EC to 2014/34/EU is now available, with a list of frequently asked questions and answers.

### 3.3.2 ISO on LNG refueling stations.

ISO is developing standards for natural gas fuelling stations for vehicles, urgently needed by the industry to facilitate the spread of this technology. The first meeting of the new ISO project committee established to develop the standards, through the creation of ISO/PC 252 "Natural gas fueling stations for vehicles", that took place in June 2010 in the Netherlands. It was decided that the Committee will have to develop two standards focusing respectively on fueling stations for compressed natural gas (CNG) and liquefied natural gas (LNG).

#### 3.3.2.1 ISO/DIS 16924.2

ISO/DIS 16924.2 “Natural gas fueling stations - LNG stations for fueling vehicles” and ISO/DIS 16923.2 “Natural gas fueling stations - CNG stations for fueling vehicles” are both under development.

#### 3.3.2.2 ISO 12614:2014

ISO 12614:2014 “Road vehicles - Liquefied natural gas (LNG) fuel system components” specifies general requirements and definitions of liquefied natural gas fuel system components, intended for use on the types of motor vehicles as defined in ISO 3833. It also provides general design principles, and specifies requirements for instructions and marking.
Specifically, ISO 12614-2:2014, which concerns performance and general test methods, is also applicable to other LNG-fueled motor vehicles (for example ships) as far as appropriate, until any specific norm would be worked out for such a type of vehicle. ISO 12614 was published in 2014 and was prepared by Technical Committee ISO/TC 22, Road Vehicles.

#### 3.3.2.3 ISO 12617:2015

ISO 12617:2015 “Road vehicles - Liquefied natural gas (LNG) refueling connector - 3,1 MPa connector”, was published at ISO level on march 2015. It specifies LNG refueling nozzles and receptacles constructed entirely of new and unused parts and materials for road vehicles powered by LNG. An LNG refueling connector consists of, as applicable, the receptacle and its protective cap (mounted on the vehicle) and the nozzle.

### 3.3.3 The Directive 2014/94/EU - DAFI

The Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the Deployment of Alternative Fuels Infrastructure - DAFI - went into force 18 November 2014.
This Directive establishes a common framework of measures for the deployment of alternative fuels infrastructure in the Union in order to minimize dependence on oil and to mitigate the environmental impact of transport. This Directive sets out minimum requirements for the building-up of alternative fuels infrastructure, including recharging points for electric vehicles and refueling points for natural gas (LNG and CNG) and hydrogen, to be implemented by means of Member States' national policy frameworks, as well as common technical specifications for such recharging and refueling points, and user information requirements. (art.1)
The Directive requires Member States to adopt national policy frameworks and notify them to the Commission two years after the enforcing of the Directive.

Art. 6 of the Directive regulates “Natural gas supply for transport” and points out that Member States shall ensure, by means of their national policy frameworks, that an appropriate number of refueling points for LNG are put in place at maritime ports and at inland ports and that the maritime and inland ports have to provide access to the refueling points for LNG also taking into consideration actual market needs. Member States shall ensure also, by means of their national policy frameworks, that an appropriate number of refueling points for LNG accessible to the public are put in place in order to ensure that LNG heavy-duty motor vehicles can circulate throughout the Union, where there is demand, unless the costs are disproportionate to the benefits, including environmental benefits etc…

In 2013, DG Move launched the EU Clean Fuel Strategy and an ambitious set of measures. In this context, directive 2014/94/EU on the deployment of alternative fuels infrastructure has been adopted in October 2014 (see par. 3.4). The directive establishes "a common framework of measures for the deployment of alternative fuels infrastructure in Europe in order to minimize dependence on oil and to mitigate the environmental impact of transports".

### 3.3.4 CEN Standardization

To support the implementation of this new Directive, DG Move developed a standardization request (Commission Implementing Decision C(2015)1330) asking CEN, European Committee for Standardization, to develop, among others, standards for LNG refueling points for motor vehicles and for maritime and inland waterway vessels for 2016 and 2017.

CEN works to promote the international harmonization of standards in the framework of a technical cooperation agreement with ISO.
European Standards are prepared by TC, Technical Committees. Each TC has its own field of operation within which a work program of identified standards is developed and executed. After its publication, a European Standard must be given the status of national standard by all CEN members withdrawing any national standard that would conflict with it.

The activity of the following technical committees is related to liquefied natural gas and gas storage:

- CEN/TC 282 "Installation and equipment for LNG" develops standards in the field of plant and equipment used for production, transportation, transfer, storage and regasification of LNG;

- CEN/TC 234 "Gas infrastructure" develops standards of functional requirements in the field of gas infrastructure (including transmission, distribution, storage, compression, regulation and metering, installation, injection of non-conventional gases, gas quality issues and others), from the input of gas into the on-shore transmission network up to the inlet connection of gas appliances. CEN/TC 234 developed a specific series of standards (EN 1918 series) dealing with 'Gas supply systems – Underground gas storage'.

- CEN/TC 326 "Natural Gas Vehicles - Fueling and Operation" covers the design, construction, operation, inspection, safety and maintenance of fueling stations and facilities for natural gas vehicles (NGV's). It includes natural gas and biomethane in compressed (CNG) or liquefied (LNG) form. The resulting standards will address the minimal safety requirements. CEN TC 326 could possibly adopt ISO 16924.2_ at European level, such a possibility is currently under evaluation.

- CEN/TC 301 "Road vehicles" could possibly adopt ISO 12617:2015, standard at European level, such a possibility is currently under evaluation.

## 3.4 Authorization processes under definition by MISE

The European Commission, with the 2014/94/EU on the development of infrastructure for alternative fuels requires that Member States produce development plans of various alternative sources for the transport sector within the year 2016.
LNG falls within this context. The directive provides that, through their national policy frameworks, Member States should ensure that, within 31 December 2025, an adequate number of supply points for LNG in maritime ports belonging to the TEN-T core network ("Trans-European Transport Network") be established and by December 31, 2030 in inland waterway ports too.

The Italian Government has undertaken, in the Parliament, initiatives for the construction of storage facilities and redistribution as well as rules for the construction of LNG with the aim of encouraging the use and to reduce the environmental impact of transport by sea and by road.

MISE - Italian Ministry of Economic Development, through the creation of a national coordination group has prepared a draft of a National Strategic Plan on the use of LNG in Italy, which analyzes different aspects: regulatory, technical, economic, safety and social impacts of this technology in maritime and trucking transports, limited to heavy transport (trucks, buses, trains).

The National Strategy Plan focuses on some specific aspects of LNG market:

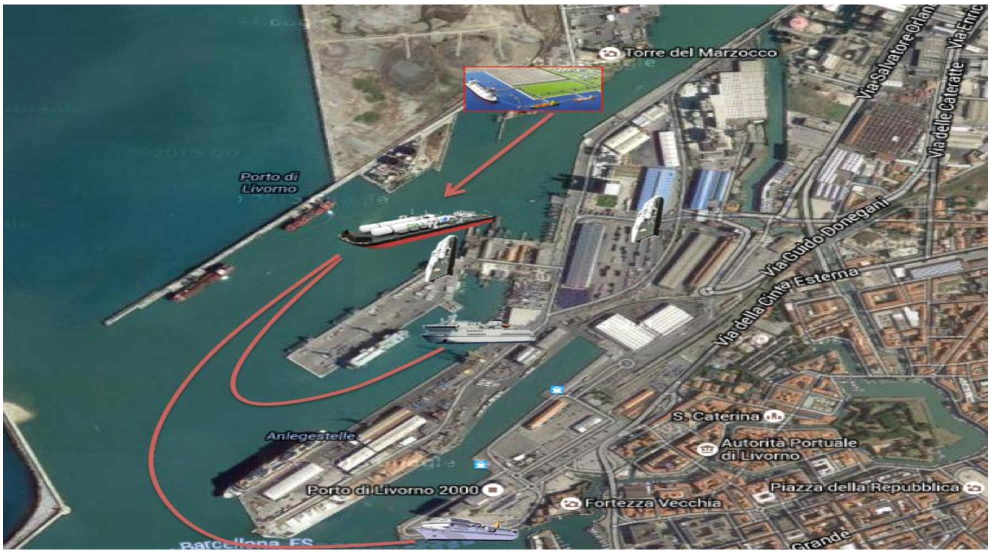
- evaluation of main experiences in European Countries, such as North Europe and Spain, that use LNG in land and maritime transport (technologies, legislation, faced problems and solutions);
- analysis of measures for adaptation to LNG of national ports covered by the TEN-T
- analysis of criteria for the identification of ports on which to install LNG storage facilities of large and medium size;
- use of LNG in heavy road transport, specifically truck and bus;
- cost analysis for transformation of ship, bus and truck to LNG;
- market potential of LNG and its impacts on infrastructures, both existing and to be converted;
- considerations on other uses: industrial, civil, use of CNG transport;
- main experiences in countries that use LNG in maritime transport and as a fuel;
- social acceptance, analysis of safety aspects, financing facilities for LNG development;
- list of most important international and European regulations regarding LNG (ISO and IMO, etc…).

The National Coordinating Group involved in the LNG is made up of MISE, with the role of Coordinator, the Ministries of Transport, Environment and Interior, Regions, ANCI (Associazione Nazionale Comuni Italiani), Port Authorities, Associations, managers of LNG Terminals, research centers such as RINA and CIG (Comitato Italiano Gas), Universities, ENEA and other stakeholders.
The document is currently under public consultation on MISE website, with the aim of receiving a feed-back from stakeholders; at the end of the consultation, a document will be drawn containing the national strategy for LNG, that will point out concrete goals to be achieved, suggested time-tables and expected measures for its implementation.

# 4. Identification of Cryo-container application scenarios

The use of Cryo-containers to transport LNG can be successfully applied to more scenarios of application, which are analyzed in this chapter. Each of them could be implemented also with traditional solutions (i.e. bunker ships and tanker trucks), nevertheless the Cryo-container solution can allow significant improvements, as duly explained in chapter 5. Each examined scenario is based on the presence of a Cryo-container terminal within Livorno Port (node 2), fed from OLT platform (node 1) and transferred by a container-carrying barge from OLT to the terminal, and by container trucks to the land terminal (node 3). Chapter 6 provides a detailed description of the main components characterizing each scenario.

## 4.1 LNG refueling of ships inside the port




LNG Cryo-containers are taken from the Livorno port terminal (node 2), where they are stacked, loaded on barges best suited for port service to LNG powered ships berthed in the port; no specific manipulation must be done in the terminal, only a normal container loading operation made by a reach-stacker of the same type already present in the terminal.

## 4.2 LNG supply to land stations (node 3).

ISO Cryo-containers are transported from Livorno Port Terminal to LNG distribution stations by any container trailer (truck or train).

In the distribution station LNG can be supplied directly to LNG powered trucks, or transformed into CNG for refueling this type of vehicles. The distribution station shall be positioned along or near an important road in order to facilitate access by the largest amount of trucks and cars. In the map a possible location is shown at the SGC FI-PI-LI or by the Interport Amerigo Vespucci, but other locations along the SGC FI-PI-LI can be considered.

Presently, LNG land terminals (Piacenza, and shortly Prato and Pontedera) are refueled by trucks coming a long way from Barcelona. Livorno port terminal will easily replace Barcelona for all land terminals located in Northern Italy.

## 4.3 LNG supply to other ports


LNG distribution from Livorno terminal to other ports of the North Tyrrhenian area can be done by Cryo-containers using a container carrier of the type normally used in the Mediterranean network of container feeders. The first advantage is that no special ship will be needed, since a network of container feeder lines is presently serving Northern Tyrrhenian ports.

The second advantage is that in the destination port there is no need for special investment and long realization times to build a coastal deposit based on traditional tanks. The only need is to reserve a dedicated area to manage and store Cryo-containers, the area being equipped with reach stackers or other facilities normally used in a container terminal.

From the Livorno LNG terminal (node 2), Cryo-containers can be shipped to different final users in the destination port:

- LNG-powered ships berthed in the destination port;
- LNG vehicles operating inside the destination port;
- LNG land stations outside the destination port, where Cryo-containers can be easily transferred.

It is important to underline that any destination port that decides to adopt this solution can rapidly, and with a limited investment, be put in a condition of supplying LNG ships in a preliminary phase; in a second phase, depending on the set-up of LNG market, an up-grade of the infrastructure will be possible, with a traditional coastal tank deposit in addition to the Cryo-container deposit.

## 4.4 LNG Cryo-container as an on-board tank for ships.

LNG Cryo-container can be used also as an on-board tank for direct fueling a dual-fuel ship, the modifications for accepting a Cryo-container on-board being quite simple. The basic idea is that, whenever bunkering facilities are not available or bunkering is not possible, an LNG Cryo-container can be directly embarked on the boat and used to power it.

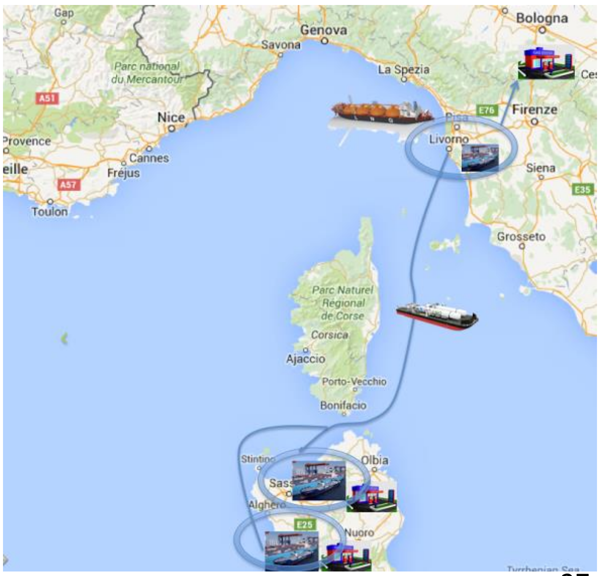
A fuel gas handling system utilizing removable LNG fuel tank containers is an option applicable to small and medium sized vessels, which do not require a large LNG capacity; such a solution offers a viable alternative to conventional stationary LNG tanks.

As an example of such an application, Wärtsilä developed a specific LNGPac ISO package, including a docking station and an evaporator skid installed permanently on the LNG-fueled ship. The fuel tank is an IMO type C pressure vessel enclosed within an outer tank; both the inner and the outer tanks are made of stainless steel, which means that the outer enclosure will act as a secondary containment. The LNG fuel tank container is fitted with process equipment, namely valves and instruments required for operational and safety purposes. The ISO Cryo-container complies with regulations for use as an onboard marine LNG fuel tank. For further simplification, the LNG fuel tank container is fitted with a pressure build-up evaporator (PBE) for building up and maintaining an operational pressure of approximately 5 bar (72 psi) in the tank. No pouring off operations are necessary.

The operations to unload empty containers and load full containers on board are very simple, requiring a time similar to normal containers; this characteristics is very useful for ships staying a short time in the port, like ferries, which by the way are the first candidates for adopting LNG.

## 4.5 LNG supply to methane distribution networks.

ISO Cryo-containers can also be utilized to support Methane distribution networks in remote areas. A significant example is given by Sardinia or Corsica methane distribution network. Such a scenario is very likely, due to the reduced distance between Livorno and the two islands, and the need of a reliable source of LNG for the existing gas network in the islands, which presently lacks of a reliable product supply.



## 5. Expected benefits

One of the main purposes of an LNG project is to find good solutions and manageable ways of establishing LNG in ports, in order to supply LNG to end users, both on the sea side and the land side, according to the demand.

Whenever the dimension of the demand is poor, or impossible to define in short times. or if the environmental conditions of the selected site (limited space or other constraints) appear to be critical, the Cryo-container may be the proper solution.
Port Authorities are usually reluctant to create a fixed costly port infrastructure, on a valuable quay, in front of an undefined start-up demand or an unreliable growth projection.
There are several issues that need to be considered with applications for LNG bunker operations and the establishment of LNG terminals: technical, financial, security, risk and safety aspects, and regulations above all.
From a regulatory perspective, an LNG project can be divided into two parts: the maritime side which is usually regulated by the Maritime national Authorities, and the land side that is usually covered by National and Regional authorities. Since road transport is regulated by the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) applicable from 1 January 2013, Cryo-containers depend on this type of regulation, so there are no critical issues from this point of view.
For what may concern in-land and small ships, berthed at the pier, issues are same as those to be applied to the tanker trucks.
For what may concern the issues of stocking a set of LNG containers, the operating modes are the same of stacking dangerous cargo containers in a dedicated container terminal yard.

For these reasons the implementation of the first port LNG deposit based on ISO Cryo-containers appears to be the most competitive and less risky also in financial terms. The installation is basically modular, and it will grow container by container with limited investment, according to the demand, until the required volumes will justify the installation of a large fixed LNG tank storage.
The above means that Cryo-container is the ideal solution for starting an LNG operation until substantial volumes are reached.

**ISO Cryo-container Transport general advantages:**

- modularity and stacking
- rapid deployment
- existence in most ports of dedicated equipment for handling
- service truck (container trailers)
- dedicated ships (feeder/container ships)
- fully intermodal approach
- maximum storage efficiency (stacking)
- logistics simplified end user/transfer of LNG to remote distributors.

**Ideal markets for ISO Cryo-containers:**

- new LNG Markets
- small-medium demand size
- medium distance <= 300 nmiles
- island users
- inland deposits

Since the Mediterranean is a rather new field for LNG diffusion, it may be useful to analyze examples of LNG set-up in new markets. In the US, this strategy was adopted in new and isolated markets in the Caribbean, Gulf of Mexico, and the Hawaii islands. In the last example (Hawaii) all LNG supply was based on Cryo-containers only.

The following table summarizes advantages and disadvantages of Cryo-containers in the 5 scenarios.

| **SPECIFIC ADVANTAGES AND DISADVANTEGES IN THE PREVIOUS SCENARIOS** | | | | | |
|---|---|---|---|---|---|
| **Requirements** | **LNG refueling inside the port** | **LNG Supply to other Ports** | **LNG Supply to Road Stations** | **LNG as an on-board tank for Ships *(1)*** | **LNG Supply to Methane distribution networks *(2)*** |
| **Infrastructure build up** | None, if container handling capabilities are already present. | Container handling and storage capabilities at the unloading port maritime terminal facility | Required to host the Cryo Container as Station tank in a secured yard space | Not required | Container handling capabilities at the unloading MDNT maritime terminal facility |
| **LNG transfer** | None (Drop & Swap Operation) | None (Drop & Swap Operation) | None (Drop & Swap Operation) | None (Drop & Swap Operation) | None (Drop & Swap Operation) |
| **Tanker truck operations** | None (Cryo-containers are loaded on simple trailers) | N/A | None (Cryo-containers are loaded on simple trailers) | N/A | N/A |
| **LNG Bunker vessel** | None Cryo-containers are filled at FSRU Station | None (Cryo-containers are loaded on container feeder ships) | N/A | None (Drop & Swap Operation) | None Cryo-containers are loaded on container feeder ships |
| **Implementation times** | Short (if there are container handling capabilities already in place) | Short (if there are container handling capabilities already in place) | Short | Short | Short (if there are container handling capabilities already in place) |
| **Implementation costs** | Low | Low | Low | Low | Low for low-medium range LNG volumes, High for large volumes |

*(1)* Obviously, as already said, other possibilities are:

- to stack the LNG Cryo-container on board and then to pump LNG into the ship fuel tanks, or
- to transfer LNG from a Cryo container tank positioned along the wharf and the ship fuel tank.

In both cases there will be LNG transfer.

*(2)* In the case of LNG Supply to Methane distribution networks based on the Tyrrhenian sea, not only large islands (Sardinia) but also smaller islands may be commercially attractive. LNG environmental benefits (lower emissions of $CO_2$, $SO_2$, $NO_x$) could give significant motivations, for small and medium size isolated energy centers, to switch to natural gas.

# 6. Comparison between Cryo-containers and bunker ships / tanker trucks solutions.

The potential LNG logistics network of the Port of Livorno, in terms of physical management of the liquid gas from the primary loading operation to the final distribution, is based on three fundamental nodes: the OLT platform (NODE 1), the Port LNG terminal (NODE 2) and an Lng/CNG refueling station (NODE 3) both for heavy trucks and for light van and cars, located close to the port in the intermodal area.
Different solutions for transferring gas through this chain, the first-one more traditional based on the use of bunker ships and tanker trucks, the second-one more innovative based on the use of Cryo-containers, are analyzed in this chapter, identifying the main physical components in each solution.

It must be underlined that is quite obvious to consider OLT as the LNG supplier, due to its position near Livorno port, but it's not mandatory. in case, for any reason, LNG provision from OLT platform could not be possible, the solutions analyzed in this chapter remain valid, with the only difference that bunker ships should arrive from other sources in the MED area.


**NODE 1 - The OLT Platform**: FSRU Station - Floating Storage Regasification Unit, developed by OLT - Offshore LNG Toscana S.p.A. (OLT in the following) is one of the most important projects of national interest in the energy sector.
The connection to the mainland for transferring CNG is guaranteed by a pipeline of about 30 km run by SNAM Rete Gas as part of the domestic network of gas pipelines.
The project followed a complex procedure of authorization under Article 8 of Law 340/00, which ends with the advice and the full positive consent by institutions and stakeholders, both locally and nationally (Decree of the Ministry of Economic Development of 23 February 2006).
With regard to the gas pipeline project, OLT delivered to SNAM Rete Gas, as already mentioned, the management of all permits relating to its establishment and operation for both the sea and the ground installations.
Now the platform is not equipped for a direct transfer of LNG towards other vessels (i.e.: LNG barges, bunkers ships, etc.), but the conversion study was already commissioned.

**NODE 2 - The Port LNG Terminal**: the construction of an LNG terminal is planned in the port of Livorno, capable of serving potentials users such as: ship at the piers, service vessels, motor vehicles and trucks, barges for port service, shuttle bunker barges for serving other ports and small/large islands.

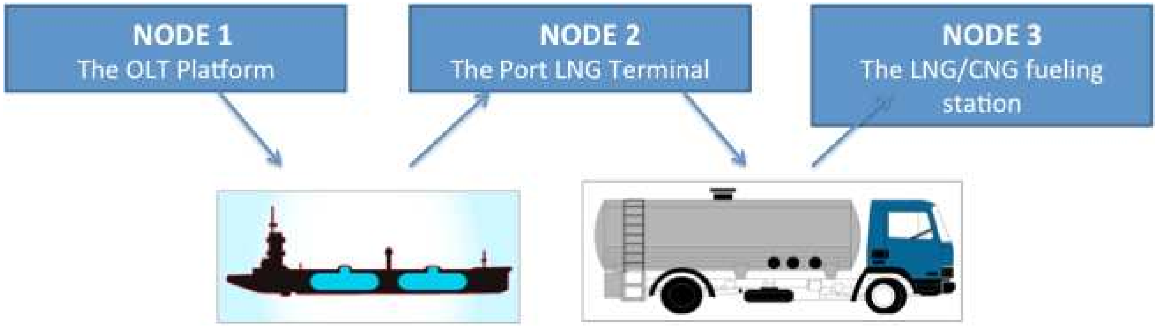
**NODE 3 - The LNG / CNG refueling station at the dry port**: on the outskirts of the port of Livorno, close to the main concentration of the fleets of heavy vehicles, the construction of a station is planned for the distribution of both LNG to heavy vehicles and CNG to light vehicles and cars.

For the connection between the three nodes of the chain, the following different solutions have been identified:

- **Solution 1**: bunker barges to transfer LNG from OLT to the Port Terminal;
  tanker trucks to transfer LNG from the Port Terminal to the refueling station;
- **Solution 2**: Cryo-containers to transfer LNG from OLT to the Port Terminals;
  Cryo-containers to transfer LNG from the Port Terminal to the refueling station;
- **Solution 3**: bunker barges to transfer LNG from OLT to the Port Terminals;
  Cryo-containers to transfer LNG from the Port Terminal to the refueling station.

The three solutions are analyzed in the following paragraphs.

## 6.1 Solution n.1: LNG transfer using bunker ships and tanker trucks




### 6.1.1 LNG from OLT Platform (NODE 1) to Port LNG Terminal (NODE 2)

The transfer of LNG between NODE 1 and NODE 2 takes place by using **LNG Bunker Barges (bettoline, from now on indicated as LBB)**. Loading LNG into the bunker ship requires transferring LNG stored in the tanks of the regasification terminal into the LBB.
The vessels loaded (LBB) can be used as a service barge which supplies LNG to other vessels, such as ships or shuttle feeder for the feeding of Coastal storage terminals in other ports.
The main actions necessary to provide this service are as follows:

**NODE 1:**
Implementation related to NODE 1 to host LBB with a loading capacity of between **1.000 $m^3$ (small LBB)** to **7.500 $m^3$ (large LBB)** and a length between 60 m to 110 m with a loading capacity of between 250 and 900 $m^3$/h.
This implementation is in charge to OLT, and has already been studied, as stated before.

**NODE 2:**
Implementation related to NODE 2 are the following:

- adaptation of the wharf infrastructure to accommodate the operational superstructure to allow berthing of LBB;
- development of the system for LNG transfer from LBB to land storage tanks;
- development of the system for transferring LNG from the storage tank of the Terminal to the different type of vessels (both small LBB and large LBB);

- supply line for the transfer of LNG from the tank to the vessels using LNG as fuel (direct consumption), and to small and large LBB;
- plant for recovery of boil-off gas (BOG) in different operating conditions (when the system is stopped or when the system is running).

### 6.1.2 LNG from Port LNG Terminal (NODE 2) to LNG/CNG refueling station (NODE 3)

The transfer of LNG between NODE 2 and NODE 3 takes place by cryogenic tanker trucks.

**NODE 2:**
The main actions necessary to provide the service loading tankers through NODE 2 are:

- equipment for receiving tanker trucks by road;
- creation of loading lines from the terminal tank to the tanker trucks;
- inclusion in the plant of appropriate cryogenic pumps to provide the necessary pressure in all conditions of plant operation;
- implementation of auxiliary components to assure safe operations:
  - creation of the vapor return line;
  - set up of an ad-hoc measuring system to assess the quantity of LNG in input and output from the main reservoir;
  - cooling down of the tanker prior to LNG loading operations;
  - development of the regulation and control system for monitoring plant parameters;
  - safety systems (i.e.: emergency shut down, etc.).
- tanker truck compatibility

The specification of a tanker truck are typically the following:

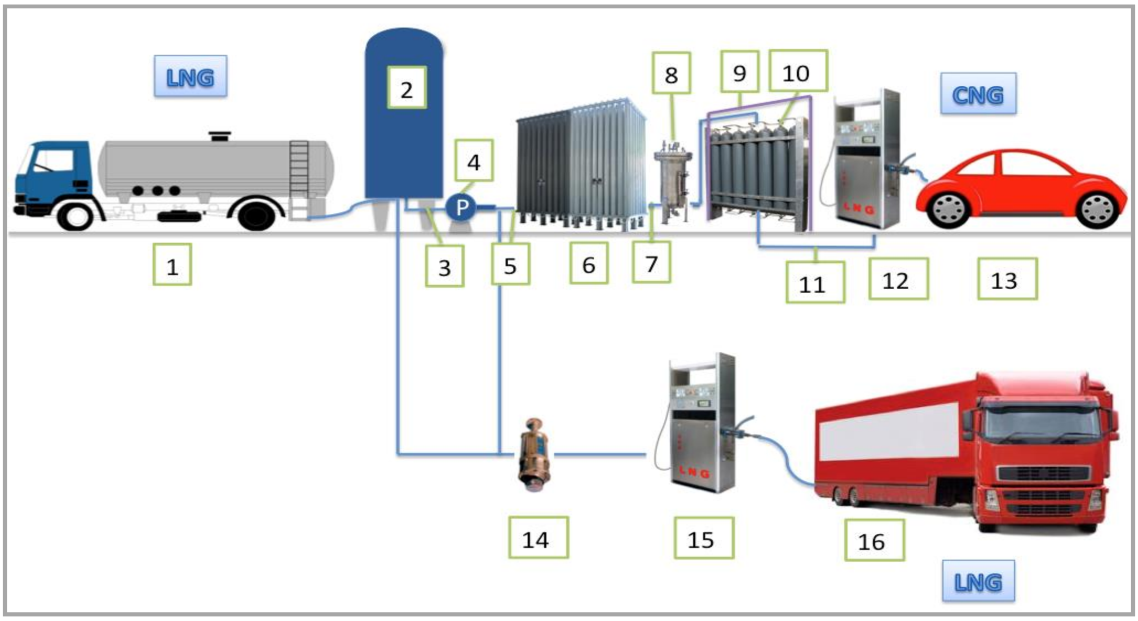
- capacity: from 15.000 to 58.000 liters
- pressure range: from 3 to 25 bar
- design temperature: -196 °C
- design codes: EN13530-2
- approvals: TPED - ADR
- insulation: Multi-layer super insulation under vacuum
- material used: outer and inner vessel in stainless steel
- outer finishing: white paint
- piping arrangement: all stainless steel pipework
- equipment included:
  - safety relief devices for both outer and inner vessel
  - pressure build-up vaporizer
  - ADR labeling and marking
  - air suspension pressure indicator
  - plumbing for normal operations

Furthermore, NODE 2 Terminal may offer, in addition to the service of loading tanker trucks, all services needed to take care of the heavy vehicles fueled with LNG, i.e.: any equipment necessary to ensure the measurement of flow and pressure, in compliance with the standard for safety of these vehicles.

**NODE 3:**

The refuelig station can support both LNG and CNG refueling components, or only one of these facilities; in the most complete configuration the main components are the following:

1 LNG tanker truck;
2 LNG main storage tank;
3 LNG pump power line;
4 high-pressure cryogenic pump;
5 LNG vaporizer supply line;
6 LNG vaporizer;
7 CNG line;
8 odorizer;
9 protection of 1st degree;
10 cylinders pack;
11 CNG line;
12 CNG dispenser;
13 CNG powered light vehicle;
14 submerged pump;
15 LNG dispenser;
16 LNG powered heavy vehicle.




Plant design must carefully consider specific aspects like:

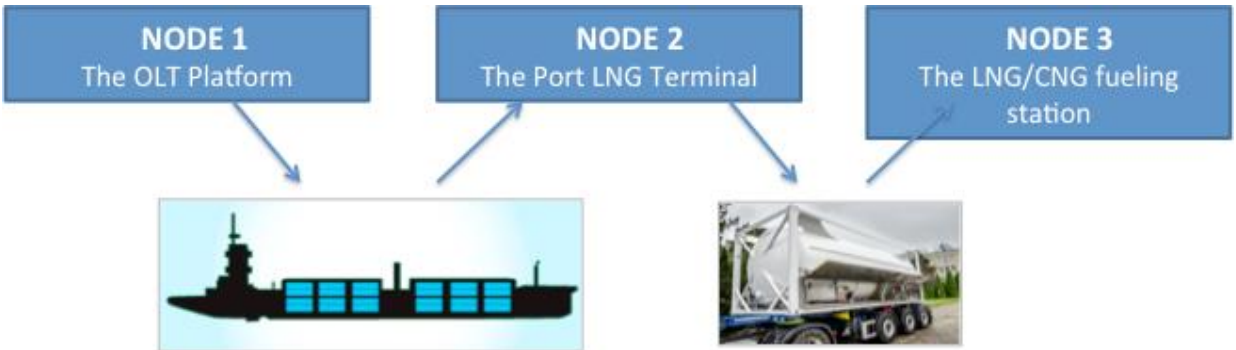
- location and urban compatibility;
- design features of the premises and components;
- types of equipment;
- safety distances;
- rules of operation;
- works for receiving tankers;
- creation of unloading lines for tankers trucks;
- carry out the works for receiving heavy vehicles fueled with LNG;

- inclusion in the plant of cryogenic pumps to provide the necessary pressure in all operating conditions of the plant;
- creation of the vapor return line from the tanks of vehicles to tanks of the plant;
- set up of an ad-hoc measuring system to assess the quantities of LNG in input and output from the main reservoir and the regulation and control system for monitoring plant parameters and safety systems.

In general, LNG stations require less material, but more safety precautions during refueling, while the CNG stations require more components and a more complex configuration. LNG is stored and distributed as a liquefied gas super-cooled, and personnel need protective clothing, face shield, gloves and other precautions to refuel a vehicle.

To distribute the CNG starting from LNG tank as a reserve, where the natural gas is stored in liquid state and kept at -162ºC and 4 bar, the liquid will be transferred and compressed by means of a cryogenic pump up to 300 bar and subsequently gasified thanks to an evaporation chamber that operates at room temperature, a process which avoids the use of energy for the gasification. The natural gas thus obtained is basically methane in its natural state, it is necessary to odorize it by means of an injection pump and store the compressed gas in high pressure cylinders generally of 80 liters capacity each.

## 6.2 Solution n.2: LNG transfer using Cryo-containers




### 6.2.1 LNG from OLT Platform (NODE 1) to Port LNG Terminal (NODE 2)

The transfer of LNG between NODE 1 and NODE 2 may be achieved through a compact container carrier designed in such a way that Cryo-containers can be loaded with LNG directly from OLT platform.
In this way, it is possible to transfer LNG in the Cryo-containers stowed on board and to move them with a container carrier from NODE1 to NODE 2.
The main actions necessary to provide this service are listed below:

**NODE 1:**
Some modifications to the NODE 1 are necessary to receive the Container carriers, whose total capacity could be of about 6.500 $m^3$ obtained with 168 ISO tank containers (each container has a capacity of over 36.000 liters). The tank containers are loaded through a single outlet load since the stored containers are interconnected by a specialized piping system (charging time 6 - 8 hours).

**NODE 2:**
No relevant modifications for the realization of NODE 2, because the container carrier can use any port facility capable of handling containers (terminal, deposits, etc.) It's only necessary to dedicate a specific area to Cryo-containers.

In this case it is not necessary to provide for direct handling of LNG to coastal deposits because each container is a supply tank of LNG itself that can be downloaded individually or in groups to other points of service at land or on-board ship for transport to remote areas, or be placed in special spaces to distribute LNG to local users.
Optionally in a second phase, in presence of a relevant increase in LNG consumption, it will be advisable to take into account the development of more complex infrastructures.

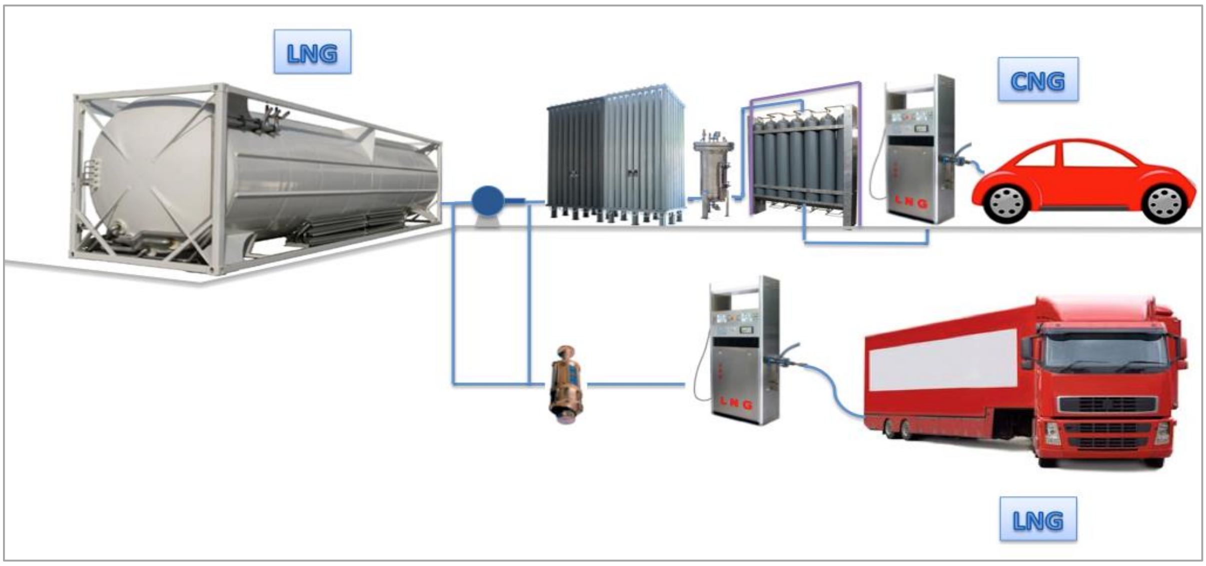
### 6.2.2 LNG from Port LNG Terminal (NODE 2) to LNG/CNG refueling station (NODE 3)

The transfer of LNG between the NODE 2 and 3 uses Cryo-containers.

**NODE 3:**
Plant developments that involves this solution are quite similar to those previously described for loading tankers trucks, with the addition of two new components:

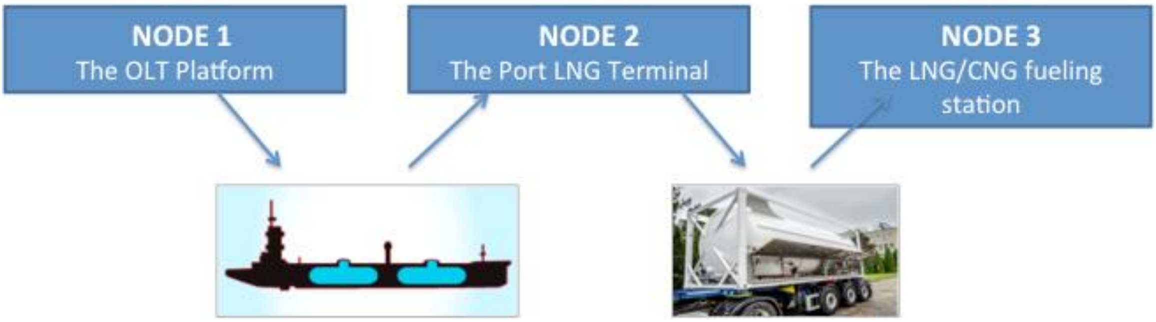
- area for receiving Cryo-containers from trailer trucks;
- lifting crane (i.e.: Reach Stacker);

LNG station will be constituted by one or more cryogenic containers placed on a special protected platform. At the edge of the container there are all the tools to manage the delivery, the pump, the measurement, the recovery of BOG, etc.
The precautions already mentioned remain valid: protective clothing, face shield, gloves and other precautions for LNG-powered vehicles.




## 6.3 Solution n.3: LNG transfer using both bunker ships and Cryo-containers

This specific solution has been analyzed because, at the moment, although a study on this subject has already been commissioned, no direct transfer is possible from OLT platform to Cryo-containers positioned on a container ship. For this reason, a hybrid solution, based on tanks from NODE 1 to NODE 2 and Cryo-containers from NODE 2 to NODE 3 is considered.




### 6.3.1 LNG from OLT Platform (NODE 1) to Port LNG Terminal (NODE 2)

This configuration is exactly the same as described in paragraph 6.1.1

### 6.3.2 LNG from Port LNG Terminal (NODE 2) to LNG/CNG fueling station (NODE 3)

This configuration is the same described in 6.2.2

## 6.4 Cost comparison

The following tables report economical evaluations related to the costs of the main components of the system, in the different solutions previously examined.

In particular:

- the first solution has been expanded in two alternatives: “full containment” double wall (30.000m³), “single containment” single wall (10.000m³).
- (“high capacity” and “low capacity”) containment;
- the third solution has been expanded in two alternatives, a basic solution and a minimal solution.

The total cost of developing an LNG fueling station depends mainly on the following elements:

- capacity of the main LNG storage tank
- site conditions
- complexity of equipment installation
- authorization processes.

Consequently, costs can vary widely from one solution to the other.

It must be underlined that the economic evaluations have been collected from different sources, reporting the costs of plants concretely realized, and from data-sheets of specific components.

<u>Considerations on LNG stations</u>
The station will distribute LNG via dedicated pumps to the different type of vessel (large LBB or small LBB) or to vehicles that will use LNG as fuel. Then a flexible pipe will transfer, via a metering device, LNG from the pump to the user (vessel or vehicle).

The main components are:

- LNG Storage Tank
- LNG Tank Foundation – ground conditioning and LNG piping.
- dispenser (Metering system, card reader, etc.)

Relevant factors to be considered are:

- station design
- project management
- station commissioning

LNG station installation costs include those associated with laying construction, trenching, ductwork, plumbing, electrical connection and material shipping and the following other costs:

- signage, lighting, and security fencing
- fueling island canopy, which may increase station cost by 25,000 to 50,000 Euro
- size and weight of vehicles to be served by the station, which affect pavement type and turn-radius requirements
- soil conditions, which can impact foundation requirements
- driveways, grading, and other general site upgrades.
- BOG (Boil off Gas) management

Considerations on CNG stations

The total cost of developing a CNG fueling station depends on a number of factors, including the fuel demand volumes and duty cycles, site conditions, the complexity of equipment installation, and authorization processes. Consequently, costs can vary widely from one project to another.
CNG stations receive fuel via a line at a pressure lower than that used for vehicle fueling. The station compresses the gas to a high pressure (200-220 bar for CNG according to Italian regulations) and store it in the dedicated cylinders (CNG storage vessels). Then a flexible pipe will transfer, via a metering device, CNG from the high pressure station to the vehicle fuel inlet.

The main components are:

- LNG vaporizer
- compressor (redundant or not)
- dispenser (Metering system, card reader, etc.)
- storage vessels

Relevant factors to be considered (Associated Balance) are:

- station design
- project management
- station commissioning

CNG station installation costs include those associated with laying concrete, trenching, ductwork, plumbing, electrical connection and material shipping and the following other costs :

- signage, lighting, and security fencing
- fueling island canopy, which may increase station cost by 25,000 to 50,000 Euro
- size and weight of vehicles to be served by the station, which affect pavement type and turn-radius requirements
- soil conditions, which can impact foundation requirements
- driveways, grading, and other general site upgrades.
- LNG vaporizer supply line
- low pressure gas line
- compressor protection enclosures
- back-up power generator
- CNG line

| Solution 1 - usage of tanks - alternative "full containment" | Value (€x1000) |
|---|---|
| **NODE 1** - Infrastructural modifications (estimated by OLT) | **2,500** |
| | |
| **NODE 2** - Terminal with minimum configuration (LNG) | **90,000** |
| LNG Storage Tank – Full Containment w/ cryo pumps (30,000 CBMs) | 45,000 |
| LNG Tank Foundation – ground conditioning and LNG piping sea and land side | 15,000 |
| Associated Balance | 30,000 |
| | |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | **14,900** |
| Small LNG Storage Tank – Single Containment w/ cryo pumps (1000 CBMs) | 2,500 |
| LNG Tank Foundation – ground conditioning | 235 |
| Associated Balance | 12,000 |
| CNG Compressor | 55 |
| Dispenser | 25 |
| CNG Storage vessels | 85 |
| | |
| **Transfers from NODE 1 to NODE 2** | |
| Large LBB (6000 CBMs) | **40,000** |
| | |
| **Transfers from NODE 2 to NODE 3** | |
| Cryogenic tanker | **360** |

The LNG tanks full containment technology widely used in large scale LNG terminals can obviously be downscaled to be installed in a small scale LNG receiving terminal. However, since the storage cost per CBM will increase when the tank capacity decreases, the suitability of the full containment technology for LNG storage tank should be questioned. The potential alternatives could be either single containment API type metallic tank if available space allows it, or full containment tank with outer container in 9% Ni or Stainless Steel, or double membrane inner container with low temperature Carbon Steel outer tank.

This second alternative may reduce cost to less than one half.

| Solution 1 - usage of tanks - alternative "single containment" | Value (€x1000) |
|---|---|
| **NODE 1** - Infrastructural modifications (estimated by OLT) | **2,500** |
| | |
| **NODE 2** - Terminal with minimum configuration (LNG) | **51,000** |
| LNG Storage Tank – Single Containment w/ cryo pumps (10,000 CBMs) | 22,000 |
| LNG Tank Foundation – ground conditioning and LNG piping sea | 14,000 |
| Associated Balance | 15,000 |
| | |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | **14,900** |
| Small LNG Storage Tank – Single Containment w/ cryo pumps (1000 CBMs) | 2,500 |
| LNG Tank Foundation – ground conditioning | 235 |

| | |
|---|---|
| Associated Balance | 12,000 |
| CNG Compressor | 55 |
| Dispenser | 25 |
| CNG Storage vessels | 85 |
| | |
| **Transfers from NODE 1 to NODE 2** | |
| Large LBB (6000 CBMs) | **40,000** |
| | |
| **Transfers from NODE 2 to NODE 3** | |
| Cryogenic tanker | **360** |

Cryo-container costs range from 35.000 Euro for 20' and 50.000 for 40', and may change depending on the selected manufacturer.

Obviously according to the operations intensity a greater or a lower number of units will be required. This does not appear as a critical issue, since it allows to align investment with demand.

As an example, It will be possible to start operations with 10 units of 20' with a total capacity of about 200 CBMs with an estimated investment of 350,000 Euro, and later plan for a stock of 20 units of 40' for a global capacity of 800 CBMs and a total investment of 1,000,000 Euro.

Therefore the maximum cost with a full Cryo-container approach will be between 13,5 and 15 million Euro.

| Solution 2 - usage of Cryo-containers | Value (€x1000) |
|---|---|
| **NODE 1** - Infrastructural modifications (to be estimated by OLT) | **t.b.d.** |
| | |
| **NODE 2** - Terminal with minimum configuration (LNG Mobile containerized stations) | **200** |
| LNG station supported by 4 units LNG Mobile containerized stations (40 feet) | |
| | |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | **450** |
| LNG station supported by 4 units LNG Mobile containerized stations (40 feet) | 200 |
| CNG Compressor | 55 |
| Dispenser | 25 |
| CNG Storage vessels | 85 |
| Associated Balance | 85 |
| **Transfers from NODE 1 to NODE 2** | |
| Container Feeder (400 TEUs) equipped to load Cryo-containers | **10,000** |
| | |
| **Transfers from NODE 2 to NODE 3** | |
| Container trailer truck | **180** |

| Solution 3 - mixed use of tanks and Cryo-containers | Value (€x1000) |
|---|---|
| **NODE 1** - Infrastructural modifications (estimated by OLT) | **2,500** |
| | |
| **NODE 2** - Terminal with minimum configuration (LNG) | **51,000** |

| | |
|---|---|
| LNG Storage Tank – Single Containment w/ cryo pumps (10,000 CBMs) | 22,000 |
| LNG Tank Foundation, ground conditioning and LNG piping sea and land side | 14,000 |
| Associated Balance | 15,000 |
| | |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | **450** |
| LNG station supported by 4 units LNG Mobile containerized stations (40 feet) | 200 |
| CNG Compressor | 55 |
| Dispenser | 25 |
| CNG Storage vessels | 85 |
| Associated Balance | 85 |
| **Transfers from NODE 1 to NODE 2** | |
| LBB (6000 CBMs) | **40,000** |
| | |
| **Transfers from NODE 2 to NODE 3** | |
| Container trailer truck | **180** |

| **Solution 3 minimum structure - mixed use of tanks and Cryo-containers** | **Value (€x1000)** |
|---|---|
| **NODE 1** - Infrastructural modifications (estimated by OLT) | **2,500** |
| | |
| **NODE 2** - Terminal with low profile configuration (LNG) | **530** |
| LNG Storage Tank – Single Containment w/ cryo pumps (**50** CBMs) | 450 |
| LNG Tank Foundation, ground conditioning and LNG piping sea and land side | 30 |
| Associated Balance | 50 |
| | |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | **450** |
| LNG station supported by 4 units LNG Mobile containerized stations (40 feet) | 200 |
| CNG Compressor | 55 |
| Dispenser | 25 |
| CNG Storage vessels | 85 |
| Associated Balance | 85 |
| **Transfers from NODE 1 to NODE 2** | |
| LBB (**6000** CBMs) | **40,000** |
| | |
| **Transfers from NODE 2 to NODE 3** | |
| Container trailer truck | **180** |

## 6.5 Delivery times comparison

The time required to build an LNG import terminal generally does not vary with the size of the structure. Rather, it is determined by the program of construction for the storage tanks, which are the most expensive components of the complex and which require the longest time to build. Storage tanks of LNG require at least two years for their construction and testing.

| Tank solution | Time Months |
|---|---|
| **NODE 1** - to be estimated by OLT | |
| **NODE 2** – LNG loading operations from the LBB and the Terminal storage tank | 24 |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | 18 |
| LBB | 20 |
| Cryogenic tanker | 12 |

| Cryo-container solution | Time Months |
|---|---|
| **NODE 1** - to be estimated by OLT | |
| **NODE 2** - Terminal with minimum configuration using Cryo-containers as storage tank | 3 |
| **NODE 3** - Gas Station with minimum configuration (LNG&CNG) | 6 |
| Feeder container ship | 9 |
| Cryo-containers | 2 |

## 6.6 Operational times comparison

| Tank solution | Hours |
|---|---|
| **NODE 1** - to be estimated finally by OLT (Loading LBB) | 6-8 |
| **NODE 2** – LNG unloading operations from LBB to Terminal storage tank | 8 |
| **NODE 3** - LNG unloading operations from Terminal storage tank to Cryogenic tank | 4 |
| Transfers | |
| From NODE 1 to NODE 2 berthing times included | 2 |
| From NODE 2 to NODE 3 | 1 |

| Cryo-container solution | Hours |
|---|---|
| **NODE 1** - to be estimated by OLT (Loading the Feeder ship) | 6-8 |
| **NODE 2** – Single Container unloading operation from Feeder ship to Terminal yard | 0,10 |
| **NODE 3** – Single Container picking from Terminal yard and loading on Container truck | 0,10 |
| Transfers | |
| From NODE 1 to NODE 2 | 2 |
| From NODE 2 to NODE 3 | 1 |

## 6.7 Risks and compatibility comparison

Some general assumptions are at the basis of the following risk comparison between tank and Cryo-container solutions.

**LNG Safety Fundamentals:**

- Liquid-state LNG is not flammable;
- ignition and burning requires vaporization and mixture with oxygen (air);
- LNG vapour is flammable; the temperature necessary to ignite natural gas is about 538 °C, while gasoline requires only 232 °C;
- burning is not sustainable outside the flammability limits (5% to 15% air, above 15% there is not enough air; below 5% there is not enough fuel;
- LNG produces a "lazy flame" which burns more like a candle and not like gasoline;
- LNG vapour cloud in the atmosphere will not explode, unlike propane;
- LNG is not shipped or stored under high pressure ( -162 °C at low pressure).

**Elements of attention:**

- LNG requires higher CAPEX for storage and distribution than traditional residual and distillate fuels;
- LNG has BOG issues that require attention;
- most of LNG related accidents happened during LNG transfer (pouring off), but in containerized operations generally there is no liquid transfer;
- release of unburned Methane contributes to the Green-House Effect more strongly than CO2;
- legislation on onshore terminals of small and medium size;
- availability of sites within ports or at industrial sites;
- implementation costs;
- confidence in the permanence of current fiscal regime on gaseous fuel.

**Mobile container solution:**

- delivery and storage of LNG in mobile container tanks is a flexible feeder option which gives a quick start- up of the market in areas where no other LNG infrastructure is available;
- the LNG storage tank is installed in a sturdy frame as a mobile container of ISO standard size, normally called 20' or 40';
- the ISO Cryo-container type of unit is approved for transportation under internationally accepted regulations: the IMO Code for Dangerous Good (IMDG) at sea and the ADR for road transport;
- Cryo-containers can be handled by ship-to-shore gantry cranes in port terminals and loaded to ADR trucks and semi-trailers for delivery to LNG users, (e.g. bunkering of LNG in small ports or to remote in-land service stations);
- the Cryo-containers can be fully equipped for connection to site installations and loading/unloading of LNG;
- whenever a Cryo-container is going to be used used as storage tank at in-land installations the service station shall follow the same regulations as for siting of a standard LNG storage tank;
- containers could also be delivered to and used on board of ships for storage of LNG, instead of normal bunkering; this option is very valuable in term of safety.

**The Cryo-container solution is oriented towards:**

- small-Scale LNG Receiving Terminals
- small-Scale LNG Shipping solutions

The development and operation of LNG bunkering facilities require due attention to safety and the use of risk assessment techniques in order to evaluate safeguards and demonstrate compliance with regulatory targets.

The risk always depends on the planning, design and development of LNG bunkering facilities, but above all

it depends on the way of operation and the correct use of detailed check-lists to support operation management and emergencies carried out by well trained people.
Risk and safety aspects are a significant part of the project whenever an LNG terminal and LNG bunkering possibilities are planned and outlined.

As LNG bunkering to ships is relatively new, available accident records cannot be used to derive accurate accident statistics and probability figures.
There are not yet established standards, consolidated and shared, for LNG bunkering installations and procedures, however, there is a number of guidelines and recommended practices concerning risk assessments presented by ISO and other recognized organizations which should be considered:

- Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface - ISO/DTS 16901, 2013-02-20;
- Guideline for systems and installations for supply of LNG as fuel to ships – OGP Draft 118683, 2014-01-16;
- Guidelines on LNG Bunkering, Bureau Veritas, July 2014;
- Recommended practices – Development and operations of liquefied natural gas bunkering facilities, DNVGL, DNVGL-RP-0006:2014-01.

Hazards associated with the introduction of an LNG terminal can be identified in a number of operational phases, such as import, truck loading, railroad loading, bunker vessel loading and LNG bunkering.
LNG hazards result as being mainly due to the physical and chemical properties, cryogenic temperatures, dispersion characteristics, and flammability characteristics.

In the following table the main aspects related to risk assessment are compared in the two solutions, based respectively on tank storage or Cryo-container utilization.

| **SAFETY RISK COMPARISON CRYOTANKER versus CRYO-CONTAINER** | | |
|---|---|---|
| **Operations** | **Cryotank** | **Cryo-container** |
| **General** | Bunkering:<br>LNG transfer with spill risk; most LNG accidents have occurred during LNG cargo handling<br>**(HIGHER RISKS)** | Containerized LNG: Limited transfer of LNG; Handling of IMDG containers is standard practice in container port; Uses existing multi-modal infrastructure<br>**(LOWER RISKS)** |
| **NODE 1 operations** | Mainly fire and explosion related to leakage of LNG or grounding and collisions.<br>**(SAME RISK LEVEL)** | Mainly fire and explosion related to leakage of LNG or grounding and collisions.<br>**(SAME RISK LEVEL)** |
| **NODE 2 operations** | Mainly fire and explosion related to leakage of LNG or grounding and collisions. Often bunkering will take place close to other port operation areas.<br>**(HIGHER RISKS)** | Mainly fire and explosion related to leakage of LNG or grounding and collisions. Often bunkering will take place close to other port operation areas.<br>**(LOWER RISKS)** |

| | | |
|---|---|---|
| **NODE 3 operations** | Mainly fire and explosion related to leakage of LNG or grounding and collisions. Often bunkering will take place close to residential areas. **(HIGHER RISKS)** | Mainly fire and explosion related to leakage of LNG or grounding and collisions. Often bunkering will take place close to residential areas. **(LOWER RISKS)** |
| **Sea LNG transfer from NODE 1 to NODE 2** | Bunker Vessel: Mainly fire and explosion related to leakage of LNG or grounding and collisions. Often bunkering will take place close to residential areas. Rapid Phase Transition (RPT) should be considered a risk, though proof of harm or damage from RPT has not yet been put forward. **(SAME RISK LEVEL)** | Feeder Container ship: Mainly fire and explosion related to leakage of LNG or grounding and collisions. (Note: container ships operated every day all over the world and the accident are absolutely rare). **(SAME RISK LEVEL)** |
| **Inland LNG transfer from NODE 2 to NODE 3** | Tanker Truck: Fire and explosions related to leakage of LNG as well as fatal accidents. **(SAME RISK LEVEL)** | Container trailer truck: Fire and explosions related to leakage of LNG as well as fatal accidents. **(SAME RISK LEVEL)** |

# 7. Livorno LNG Logistic system (L3)

The favorable geographical position of the Port of Livorno, the proximity to the OLT Offshore Terminal which, in perspective, will be in a position to supply LNG to all Tyrrhenian ports, the vicinity to the islands of Corsica and Sardegna, all these elements together justify the definition of a **Livorno LNG Logistic system (L3)**, for the simple reason that these considerations can hardly be matched by any other Italian port with respect to the logistics of LNG.

## 7.1 Considerations on Logistics

Characteristics and installation aspects related to Node 2 "Port LNG Terminal" and Node 3 "LNG/CNG filling station" have been till now analyzed; in this chapter the logistic aspect is examined, aiming to identify some possible sites where to position these nodes within Livorno Port and neighboring areas.

It must be underlined that this aspect is crucial and involves a lot of constraints and considerations, first of all taking into account both the existing situation and the development strategies defined by the Port Authority (see "Piano Regolatore Portuale" and "Piano Operativo Triennale" reports).

For this reason the following scenarios can be considered only as a preliminary hypothesis and a contribution to a further discussion.

**Possible positions for Port LNG Terminal (NODE 2)**

Two possible solutions have been considered:

- Solution A – area 13 Darsena Toscana Terminal; a specific area could be reserved between Torre del Marzocco and the Container Terminal, which seems to be adequate in all alternatives (tanks or Cryo-containers, or a combination of them); docking of barges (both from OLT and other LNG sources), and departing of barges (to unload inside the port or in other ports), seems to be optimal, since this location is not far from the entrance of the port;
- Solution B – area 30 Costiero Gas Livorno; this area seems more critical, due to limitations in the available space. It may be adequate in start-up and medium term, but could become a big problem in long term, due to expected relevant increase in demand. An additional aspect to be considered is the need for barges to move along the industrial canal, quite long and tight: an intense traffic could be critical for safety aspects, as often indicated by the Maritime Authority.

**Possible positions for LNG/CNG land refueling station (NODE 3)**

Two possible solutions have been considered:

- Solution A – At the road entrance of Darsena Toscana Terminal: this solution should be good both for refueling vehicles operating inside the port area or for external vehicles coming from the SGC FI-PI-LI motorway, being the site at the very beginning of SGC FI-PI-LI and Viale Mogadiscio);
- Solution B – Interporto Amerigo Vespucci: it appears to be a good solution too, due to Interporto's central position respect to SGC FI-PI-LI, to the port, to the industrial area and to the city; further investigations are needed to identify the best position inside the area, taking into account the additional space needed to ensure further developments.


## 7.2 Considerations on LNG market development.

The use of LNG as a fuel for transport is widening significantly in recent years, but volumes are still relatively small. In the road sector most of the fuel used goes to heavy vehicles and tractors, large road haulage companies or ports operations for container handling (Semi-trailer tractors, Reach stackers, etc.).
In the maritime sector the types of transport means powered with LNG fuel are expanding rapidly, including merchant ships, particularly in Scandinavia, but at a much slower pace in the Mediterranean area.
An increasing substitution of diesel with the LNG is already a reality in countries like Canada and the United States. Also in the same countries the use of LNG to fuel locomotives is being tested.
In Europe, the use of LNG is particularly developed in Spain, Norway, UK and the Netherlands, where the highest number of facilities for the LNG industry is located.
But this situation is going to change rapidly, especially if the planned enforcement of a 0.5% limit on the Sulphur content of bunker oil will take place in 2020 (or 2025 at latest).

Within this context, Livorno Port can play in the near future a strategic rule, due to the conditions already mentioned:

- the maritime position in the North Tyrrhenian area, ideal to be candidate as provider of LNG to other large ports, not far away;
- the position with respect to the Central/North-West area of Italy, most important urban and industrial centers are located;

- the OLT terminal as a potential LNG source.

In the following paragraphs a largely indicative market analysis is performed, quantifying the expected LNG demand both for road and maritime transport in Livorno area in a 2025 horizon.

### 7.2.1 Expected Road Transport market.

The new DAFI Directive 2014/94 / EU of 22 October 2014 "on the creation of infrastructure for alternative fuels", obliges Member States to ensure that, by Dec. 31, 2025, a sufficient number of outlets to LNG is installed, publicly accessible at least along the core network of the TEN-T to ensure the circulation throughout the Union of heavy vehicles powered by LNG. In order to define the specified number of points of supply, the directive proposes to take into account the minimum range of heavy vehicles powered by LNG, indicating, for example, the average range distance of 400km.
Therefore, in a highly simplified assumption, wanting to respect the average distance of 400 km, as recommended Directive DAFI, an adequate number of outlets, constituting a network of distribution of the first level, in Italy should be no less than 10. It is observed, however, that in order to ensure a level of service higher than the minimum, calibrated exclusively on the autonomy of the vehicles, a distribution network would be required, more dense - even on the road network - with a number of outlets at least double compared to what has been indicated above.
The high traffic volume in Italy is highly concentrated in the road network of the regions of northern and central Italy.

**Traffic volumes.**

A good starting point for Livorno area, in order to aggregate rapidly a major LNG market susceptible to play a leading role for the North Tyrrhenian area, is to provide three refueling points: Port of Livorno, Interporto Vespucci and Pontedera (which, to our knowledge, should be ready for 2016).
The target demand area could be identified as an area contained within a radius of 100 km around the port, since also the new or incoming refueling stations (Pontedera, Prato, etc.) on the territory will receive the liquid fuel from the main LNG storage of the port of Livorno.

For what may concern the potential road traffic volumes produced in the port of Livorno area, by December 31, 2025, it can be estimated in the following way:

- <u>Traffic due to the new containers area of Darsena Europa</u>
  - estimated Containers total traffic volumes: 1,200,000 units
  - containers to be moved by rail: 10% (120,000 units)
  - containers that activate truck road missions (90%) : **1,080,000** .

  (in 2014, in the presently limited Container Terminals infrastructure, the total traffic volume was 326,551 containers),

- <u>Industrial traffic</u>

  The industrial traffic that will affect the number of trucks missions includes
  - the activities that insist on the Port Terminals (in the Containers Terminals will operate a fleet of semi-trailer tractors, reach stackers or lifting equipment powered with LNG fuels, since real experiences were already started at Darsena Europa),
  - the Vespucci freight village,
  - the port ancillary industries,
  - the petrochemical activities in the area

The Industrial traffic could be estimated in **200,000** missions.

- <u>Traffic produced by ferries and RO-RO ships</u>
  The volumes of trucks achieved in 2014 reached more than 300,000 units. So it can be estimated that by year 2025 traffic volumes in the same sector could go beyond **600,000** units.

Therefore the overall forecast of road traffic generated by the reference area by 2025 will be of **1,880,000** trucks per year.

**Identifying LNG fuel consumption per truck**

In order to estimate the annual LNG demand volumes by year 2025, the fuel consumption rate of the tractor IVECO Stralis (330 CV) can be considered as a reference. IVECO, for this vehicle, declare an average LNG consumption rate of 28.8 kg per 100 km, which parameter is translated to $m^3$ per Km taking into account the following data and tables.

| Truck consumption of LNG per km | | |
|---|---|---|
| LNG consumption per truck (Kg/Km) | LNG density (at -163,5 °C) (Kg/$m^3$) | LNG consumption per truck ($m^3$/km) |
| 0.288 Kg/km | 468 Kg/$m^3$ | 0.0006154 $m^3$/km |

**Road LNG consumption within the reference area**

Taking into account the average range distance of 400km for each transport mission per truck, (wanting to respect the average service distance of 400km, as recommended Directive DAFI) the following total annual LNG demand for the road sector in the area will be described according to two different scenarios by year 2025:

<u>First scenario</u>: 10% of LNG powered trucks operating in the target area.

| Road LNG demand by 2025 ($m^3$/year) in Livorno's area -1.st scenario | | | |
|---|---|---|---|
| Projected LNG fueled trucks missions in the area (vehicles/year) | LNG consumption per truck ($m^3$/km) | Average mileage between refueling of each truck (Km) | Total road annual LNG demand by 2025 ($m^3$/year) |
| 188,000 | 0.0006154 | 400 | 46,278 |

Such a foreseen demand corresponds to a monthly operating intake of about 3,800 - 4000 $m^3$.

<u>Second scenario</u>: 25% of LNG powered trucks operating in the target area.

| Road LNG demand by 2025 ($m^3$/year) in Livorno's area - 2.nd scenario | | | |
|---|---|---|---|
| Forecasted LNG fueled trucks mission events in the area (n. vehicles/year) | LNG consumption per truck ($m^3$/km) | Average mileage between refueling of each truck (Km) | Total road annual LNG demand by 2025 ($m^3$/year) |
| 470,000 | 0.0006154 | 400 | 115,695 |

Such a foreseen demand corresponds to a monthly operating intake of about 9,500 – 10,000 $m^3$.

### 7.2.2 Expected Maritime Transport component.

According to data emerged from **COSTA project**, which are based on maritime transport services carried out by ships during the year 2012 on **short-haul routes** between ports "Core", it has been assumed that the 25% of the theoretical maximum potential bunkering volumes by the year 2025 will be supplied by LNG; half in the port of arrival and the other half in the port of destination.

North Tyrrhenian demand volume levels are described in the following diagram.

| **Sea LNG demand by 2025 (m³/year)** | | | |
|---|---|---|---|
| **Port** | **Total LNG potential consumption (m³/year)** | **% LNG quote** | **LNG bunkering demand (m³/year)** |
| **Genova** | 1,295,803 | 25% | 323,951 |
| **Savona** | 260,000 (*) | 25% | 65,000 |
| **Livorno** | 816,237 | 25% | 204,059 |
| **La Spezia** | 365,464 | 25% | 91,366 |

(*) The estimate includes the potential traffic generated by natural development plus the new Maersk Terminal.

In Northern Tyrrhenian, there are two potential points of supply to feed Genova and Savona: Livorno regasification terminal offshore OLT FSRU Toscana and LNG terminal at Panigaglia at La Spezia.

In the simulation it is prudently assumed that Genova and Savona could be supplied half by OLT FSRU Toscana and another half from Panigaglia, and La Spezia totally supplied by Panigaglia; according to this evaluation, Livorno Port by 2025 could meet a demand volume of around 400.000 m³/year, according to the following calculation: ((323,951+65,000)/2 + 204,059) = 398,534 m³/year.

### 7.2.3 Overall expected LNG market

Therefore, the estimated total volume of LNG demand (road plus maritime component) in 2025 in Livorno could be in the order of 450,000 m³/year, to which the volume of LNG converted into CNG for light trucks and cars (an estimate of about 5% ) should be added.

As a conclusion, an estimate of about 40,000 m³/month may be reasonable for justifying by 2025 the related investment assessment.

Obviously, there could be other demand opportunities along the Liguria coast, the Tuscany coast, or in Corsica or even in Sardinia but at this stage it is difficult to quantify these additional components.

In the assumption that in the long run oil will become more expensive and gas cheaper. conversion from diesel to LNG fuel could provide operators with sustainable cost savings of up to 30%. By using LNG as a fuel for ships, barges, coasters, ferries, as well as for heavy trucks, their carbon dioxide ($CO_2$) emissions can be reduced by up to 20%, their nitrogen oxide ($NO_x$) emissions by up to 85%, while reducing sulphur and particle emission pollution almost to zero.

For these reasons, the use of LNG as a fuel is expected to grow substantially and Livorno could be the focal point for the development of this fuel distribution in the North Tyrrhenian area, just as Barcelona is doing today, after having started successfully this process no more than three years ago, representing now the core of this industrial chain for Spain.

The key for a fast development of the LNG distribution industrial segment can be the Cryo-container.
As already described previously, the Cryo-container strategy was already adopted to supply LNG to isolated markets in the Caribbean, Gulf of Mexico, and in particular to Hawaii islands, where they succeeded in avoiding long waiting times to obtain the green light from authorities, easily building-up almost immediately LNG operations to fit demand, and aggregating in a short time a vast number of customers.
This is a consequence of the advantages of the Cryo-container approach: fast time-to-deliver, and low investment, since complex equipment to store, operate and transport LNG is not required.

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Note: Additional References on Regulations are listed in the text of Chapter 3. Applicable Regulations