EUROPEAN COMMISSION

DG MOVE

SEVENTH FRAMEWORK PROGRAMME

GC.SST.2012.2-3 GA No. 321592

Cost analysis of LNG refuelling stations

LNG Blue Corridors Project is supported by the European Commission under the Seventh Framework Programme (FP7). The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the FP7 nor the European Commission is responsible for any use that may be made of the information contained therein.

Deliverable No.	3.8	
Deliverable Title	Cost analysis of LNG refuelling stations	
Dissemination level	public	
Written By	Flavio Mariani – NGVA Europe	
Checked by	Dorian Gonzalez - GNF	
Approved by	Xavier Ribas - IDIADA	
Issue date	28/10/2016	

Executive Summary

At the time of preparation of this Deliverable, 12 refuelling stations are in operation or under construction in the Project. They are not the first LNG refuelling stations to come in operation in Europe, but they substantially add on to the total number of them (18%). They were conceived with a comprehensive network in mind when choosing locations. When it comes to the costs, some rate of uncertainty is still in place. Most of the reported figures are based on the response given by the companies building stations, who are partners of the Project. In Europe the total CAPEX of a LNG refuelling station also selling L-CNG, is within the range: 850.000 ÷ 1.150.000, but in some cases it can peak up to 1.800.000 €, not including the cost of land. Lower cost is possible, in the range: 500.000÷600.000 for stations not selling L-CNG, but this option might turn out to be a short-sighted one, because in general the CNG market is already existing, and can anyway have a faster start-up time. For this reason, even when going for this low-CAPEX option, it is advisable to include some spare place, and a set of structures ready for a subsequent easy implement with the installation of the L-CNG facility. Lower CAPEX is also possible for very small stations, for demonstration purposes and as start of market in new areas. Also small CAPEX is possible in case of mobile or muvable refueling stations, in the range: 300.000÷500.000 €.

The analysis done shows that the best option for the refuelling station is that offering both L-CNG and super saturated LNG. It is the most expensive option, generally on the higher end of the range. It is anyway also likely to provide the better turnover and a shorter pay-back time, if a NGV market is in place, or can be developed locally in a reasonable length of time, which should be the target for all EU countries, and which is a mandate of the Directory 2014/94/EU (DAFI). It is also more flexible thus more satisfactory to customer's needs. The cost vs. benefit analysis shows interesting figures starting from a sale rate in excess of 80 ton per month of fuel (LNG and CNG), and for a LNG and CNG price at the pump from 1 €/kg on. Reasonably good economical results are also possible in case of lower sale rate and price at pump, if no or very reduced excise duties are applied, or with lower CAPEX, or with a supply cost of LNG lower than the cost adopted in the analysis, i.e 20 €c/Nm^3; 29 €c/kg. The variability of the total cost is depending on a number of factors, among which there are:

- product offered, i.e. only LNG or both LNG and L-CNG;
- kind of station, i.e. mono-fuel or multi-fuel;
- chosen technology, e.g. saturated or super saturated;
- size of storage;
- flow rate of pumps;
- country where the station operates;
- lack of harmonized standards.

At this stage, it is already possible to draw the early conclusion that the Project proves quite successful as initiator, as some additional LNG refuelling stations are in good progress or have been put in operation already, and some other are planned, out of the scope of the Project, thanks mainly to the example given by its pioneering stations.

Revision History and Statement Of Originality

Revision History

Rev	Date	Author	Organization	Description
01	April 2016	Flavio Mariani	NGVA Europe	General content
02	October 2016	Flavio Mariani	NGVA Europe	Inclusion of new data
03	October 2016	Javier Lebrato	IDIADA	Revision

Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

Contents

Executive Summary 2

Revision History and Statement Of Originality 3

1 Introduction 7

1.1 LNG Blue Corridors project 6

1.2 Disclaimer 7

1.3 The analysis 7

1.4 LNG stations in LNG Blue Corridors project - Stations as of April 2016 8

2 Infrastructure cost overview 10

2.1 Technologies 10

2.2 The L-CNG operation 13

2.3 Main components of the LNG station 14

2.4 LNG technology options 15

3 Types of costs 18

3.1 Common costs 18

3.2 Variable costs 19

3.3 Common costs of stationary LNG stations 20

3.4 Variable costs of stationary LNG stations 23

3.5 Specific features of the different technologies 40

3.6 Further development of the LNG infrastructure in Europe 41

4 Operational costs of LNG and L-CNG refuelling stations 42

5 Analysis of profitability of LNG and L-CNG refuelling stations 45

6 Panoramic of LNG price in Europe 48

7 LNG sale rate of stations 50

8 Conclusions 52

9 Appendix 53

9.1 LNG trade price 53

9.2 Composition of LNG worldwide 53

9.3 Example of odorisation system for L-CNG station……………………………………………………………………..54

9.4 Example of LNG cryogenic road tanker – cost/benefit analysis LNG truck…………………………….54

1 Introduction

1.1 LNG Blue Corridors project

The LNG Blue Corridors project's aim is to establish LNG as a real alternative for medium- and long-distance transport—first as a complementary fuel and later as an adequate substitute for diesel. Up to now the common use of gas as fuel has been for heavy vehicles running on natural gas (NG) only for municipal use, such as urban buses and garbage collection trucks. In both types of application, engine performance and autonomy are good with present technologies, as they are well adapted to this alternative cleaner fuel.

However, analyzing the consumption data, the equivalence in autonomy of 1 liter of diesel oil is 5 liters of CNG (Compressed Natural Gas), compressed to 200 bar. Five times more volume of fuel prevents the use of CNG in heavy road transport, because its volume and weight would be too great for a long-distance truck. This opens the way for LNG (Liquefied Natural Gas), which is the way natural gas is transported by ship to any point of the globe. NG liquefies at 162º C below zero, and the cost in energy is only 5% of the original gas. This state of NG gives LNG the advantage of very high energy content. Only 1,8 liters of LNG are needed to meet the equivalent autonomy of using 1 liter of diesel oil. A 40-ton road tractor in Europe needs a tank of 400 to 500 liters for a 1.000 km trip; its equivalent volume with liquid gas would be 700 to 900 liters of LNG, a tank dimension that could easily be fitted to the side of the truck chassis. LNG therefore opens the way to the use of NG for medium- and long-distance road transport.

LNG has huge potential for contributing to achieving Europe's policy objectives, such as the Commission's targets for greenhouse gas reduction, air quality targets, while at the same time reducing dependency on crude oil and guaranteeing supply security. Natural gas heavy-duty vehicles already comply with Euro V emission standards and have enormous potential to reach future Euro VI emission standards, some without complex exhaust gas after-treatment technologies, which have increased procurement and maintenance costs.

Figure 1-1. Impression of the LNG Blue Corridors

To meet the objectives, a series of LNG refueling points have been defined along the four corridors covering the Atlantic area (green line), the Mediterranean region (red line) and connecting Europe's South with the North (blue line) and its West and East (yellow line) accordingly. In order to implement a sustainable transport network for Europe, the project has set the goal to build approximately 14 new LNG stations, both permanent and mobile, on critical locations along the Blue Corridors whilst building up a fleet of approximately 100 Heavy-Duty Vehicles powered by LNG.

This European project is financed by the Seventh Framework Programme (FP7), with the amount of 7.96 M€ (total investments amounting to 14.33 M€), involving 27 partners from 11 countries.

This document corresponds to the deliverable 3.8 within work package 3. It is a document describing the LNG stations cost analysis in the project. This document will be available at the project website: http://www.lngbluecorridors.eu/.

1.2 Disclaimer:

This report contains large amount of information provided by the Partners of the LNG Blue Corridors Project, who are always firms having also a business plan outside of the Project. The report is intended for circulation among a wide public, as in the general and agreed objective of the Project. Part of the provided information is anyway a subject having confidentiality aspects, as it is used in the balance books of the Companies who are the Partners. To simultaneously meet the mandate of the Project in terms of public circulation of all the documents, and the needs for confidentiality of the Partners, no connection is shown across all the report between the data included and their source. No clear clue is intentionally offered, which might allow the identification of the Partner providing the used and shown information and figures. For example, all refuelling stations have been taken as reference for operational data, as CAPEX and OPEX, but the name of any particular station operator has never been made in the report in direct conjunction to the station, nor has the relevant address been mentioned. When necessary, the stations described in the report are identified by just numbers which have no direct connection to any one of them (i.e. RS1; RS2 … or RS I; RS II…). Also the different manufacturers involved are identified in this way (i.e. M1; M2 ….). This method has been followed across the document in all the cases when the confidentiality was, or might be required. Making direct reference to the source of information would have been anyway not necessary for the aim of this report.

NOTE:

In all figures in the text, comma is used as decimal separator, and dot is used as thousands separator.

1.3 The analysis

This document aims at an analysis of the total cost of the public infrastructures needed to deliver LNG in liquid form to LNG trucks, taking into account also the option of delivering CNG to LD vehicles, obtained via LNG high pressure pump and vaporization. The costs for construction and operation of the station are examined. Different technologies are applicable; the document takes in consideration the main technologies at present adopted by manufacturers of these plants.

Some consideration has been given also to the option of mobile LNG refueling stations, as a tool to increase flexibility in the development strategy of the LNG infrastructure. Mobile LNG refuelling stations tend to have necessarily limited potential in term of total capacity of stored product (e.g. 20 m^3, i.e. ~10 ton). Hence also limited is the maximum number of filling operations per day (average amount of LNG in each filling: 115 kg). They offer anyway a high operational flexibility in terms of access of different locations based on variable needs.

The cost analysis includes:

- equipment,
- assembly,
- civil works,
- permits,
- engineering,
- operations/obligations needed for commissioning and start-up of the station in legal and safe conditions.

Building up this infrastructure is demanding high financial efforts because of the high technology value included and the still low scale effect. The aim of the document is to provide an estimate of such financial effort, and an evaluation tool of how effective and viable is the investment of financial resources in this field, taking in consideration a reasonable level of uncertainty. The level of uncertainty is anyway reducing as more stations are built on a larger part of the European territory. The increase of number of stations has the synergical effect of widening the covered area, thus encouraging new customers, and increasing the market potential of each single existing station. It is also improving the scale effect for new stations to come, and rising up the confidence of the operators in taking decisions on new, substantial investments.

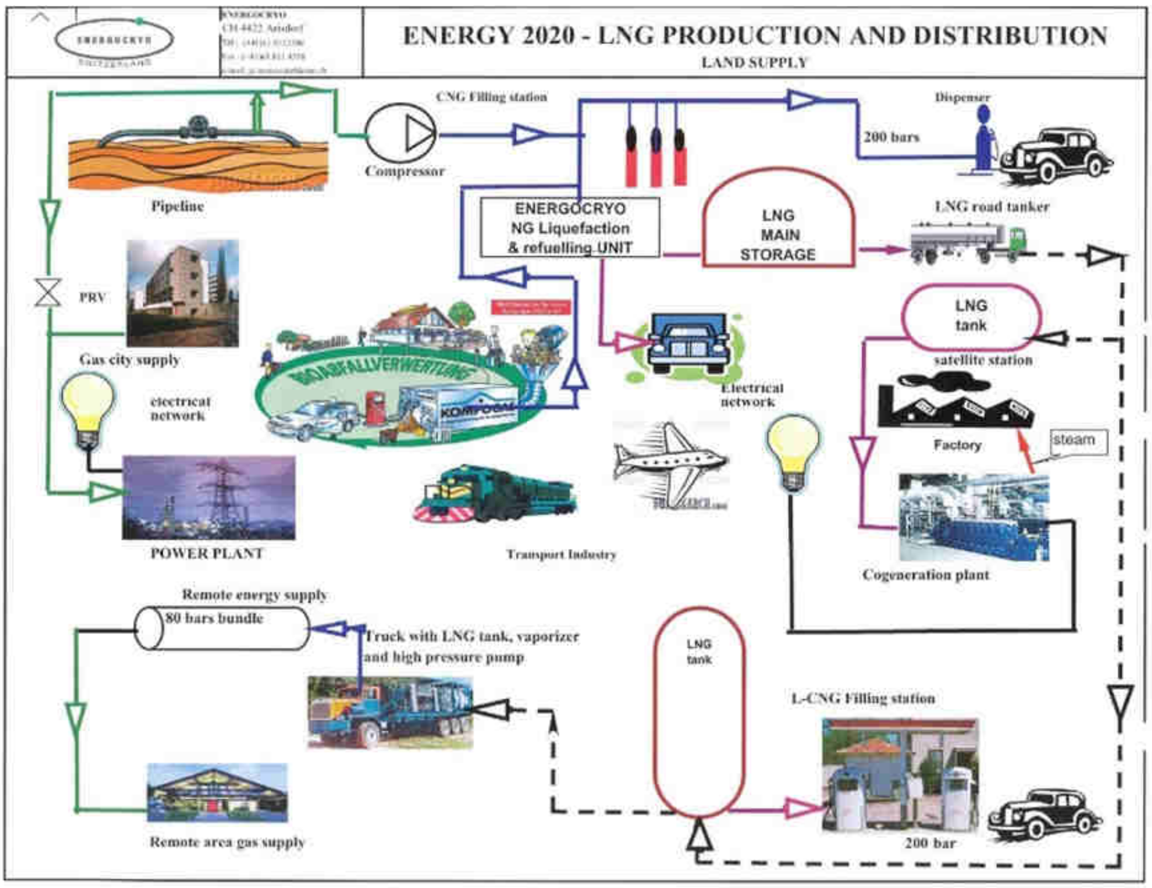


Fig 1-2 Scheme of the LNG production and utilization system [source: ENERGOCRYO]

1.4 LNG Stations in LNG Blue Corridors Project – Status as of April 2016

When this document were edited as a first draft, eight LNG refuelling stations were in full operation inside the LNG BC Project. Meanwhile, another four refuelling stations were progressing successfully. Eventually, they were put in full operation close to the end of 2016, which took the total to twelve, out of the fourteen originally planned in the Project. One more refuelling station, located in Germany, joined in on late 2016, thus completing the framework devised by the Project. The figures included in this document are relevant to the whole amount of stations covered by the project (i.e. 13 stations).

Stations in operation at the end of 2016

- Piacenza Italy ENI
- Pontedera Italy ENI
- Kallo Belgium DRIVE
- Örebro Sweden SGA
- Carregado Portugal DOUROGAS
- Elvas Portugal DOUROGAS
- Matosinhos Portugal GALP
- Barcelona Spain GNF
- Nîmes France GNVERT
- Rungis France GNVERT
- Lyon France GNVERT

Stations under construction at the end of 2016

- Sines Portugal GALP
- Berlin Germany LIQVIS

Station owners and manufacturers (the alphabetic ranking do not match that of the refuelling stations)

- CLOUD ENERGY
- DRIVE SYSTEMS
- ENGIE
- ENI
- ENOS LNG
- GALP ENERGIA
- GAS NATURAL FENOSA
- GOLD ENERGY
- HAM
- LIQVIS
- VANZETTI ENGINEERING

2 Infrastructure cost overview

2.1 Technologies

The field of LNG refueling infrastructure is technologically mature and settled. In Europe it still suffers from lack of scale effect, since as much as ~70 LNG refuelling stations are operative in Europe in 2015, not being a large infrastructure web yet. In some other parts of the world there is much more scale effect. In China at least 1.500 LNG refuelling stations are in operation. In North America there are hundreds of them.

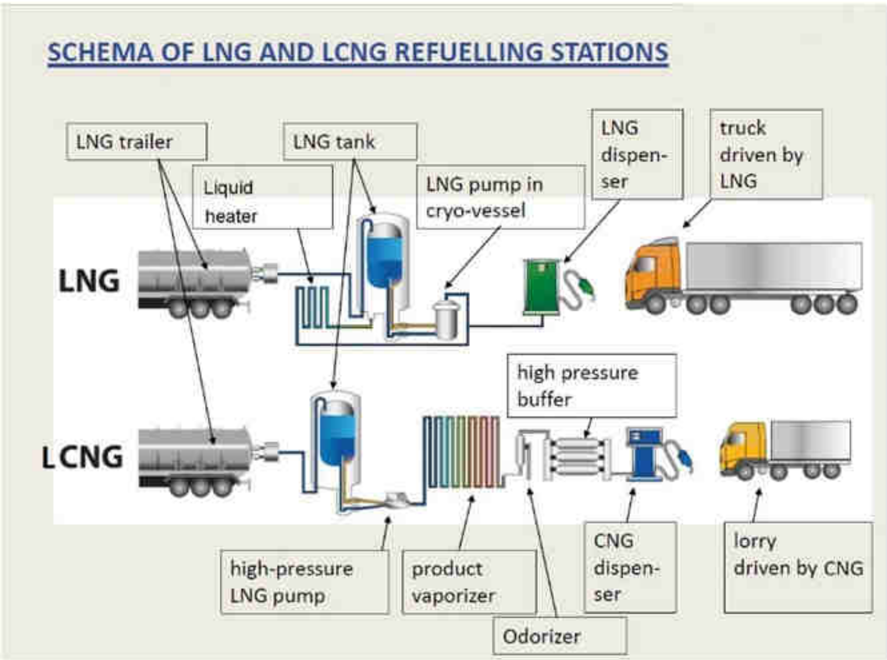


Fig 2-1 Scheme of LNG and L-CNG station

The different technologies available on the market Nowadays, in the opinion of the experts can be ranked in terms of technological complexity. They must be examined in order to determine how they match to the planned business models. They must also adopt the adequate technology for each possible application: primarily private fleets and public stations. The simpler refueling station can deliver LNG only, in which case all customers will be trucks or anyway HD vehicles; it can also be a bit more complex, and deliver both LNG and CNG, in the so called L-CNG concept. Quite often, the availability of LNG in a service station is a good reason to also adopt the L-CNG concept; it makes the station more expensive, but allows some remarkable benefits; the most important are:

- Increasing the network of CNG, that is still under developed in most of the European countries.
- Installing CNG refueling stations also in those areas where the natural gas pipeline system is less developed, and in general where the pipeline is too far; with a distance above 1 km from the grid, the connection pipe will easily cost more than the refueling station, as connection pipeline costs generally vary in the range of 300-600 €/metre.

- Starting the business also in the CNG market, for which a larger group of customers is already available in many European countries (about 1.300.000 NGV are in circulation in Europe), thus increasing the viability of the investment, even if at the cost of a larger investment.
- Not requiring necessarily a minimum fleet of HD LNG vehicles to be viable
- Producing CNG without the use of an expensive and energy demanding compressor; the L-CNG concept is based on pumping a liquid instead of compressing a gas, thus saving 90% of the energy consumption, for the same CNG end pressure of 200 bar. Typical energy consumption with compressor, intake pressure 10 bar: 0,3 kWh/Nm^3; typical energy consumption with low pressure liquid pump, intake pressure 10 bar: 0,03 kWh/Nm^3 equivalent.
- Selling a premium quality CNG in terms of stability of characteristics, and in terms of efficient filling of on-board CNG tanks, due to the lower temperature at which L-CNG is usually available; the lower the intake gas temperature, the lower also the final storage temperature, and the higher the amount of CNG (in kg) stored at the same pressure (200 bar). This benefit is more important than people normally expects; the compression of CNG in the on-board tank produces inevitably an "adiabatic" temperature rise, in case of quick fill, i.e. in normal public refueling stations. The CNG leaving the high pressure evaporator is far colder than the CNG leaving the compressor, even in case of efficient inter-stage gas cooling. This can limit to a substantial extent the heating effect in the CNG tank. With this kind of fill the customer can expect to drive longer.

Fig 2-2 energy benefit of the L-CNG option [source: CHART]

Besides this, another important parameter to distinguish the LNG refueling stations is the service pressure, also affecting service temperature, as these two parameters are strictly linked in the case of any cryogenic liquid. OEM have not yet come to an agreement on a single service pressure for the on-board system of their HD vehicles. In 2015 this ranges between 3 to 20 bar. So a station designer must choose between high design pressure, (more flexibility, complexity and installation costs), or a station focused on a limited pressure span, maybe having to renounce to some potential customer requesting for a higher pressure. The market shows anyway a general trend towards lower pressure for the future. For any given service pressure of the refueling station LNG storage tank, delivering LNG to vehicles that have a different pressure requires the use of a low pressure pump, LNG conditioning heat exchanger, to set the product to the proper temperature depending on pressure, and some energy consumption for pumping. The *Fig 2-3* shows some example of LNG on-board service pressures adopted by manufacturers in 2014; these example generally refer to first generation models; this is subject to changes over time. In future there might be a tendency to more harmonization of the service conditions; the present market already shows some signs of this happening. This would make life easier for manufacturers and operators of refueling stations; and would be also beneficial in terms of a bit lower CAPEX.

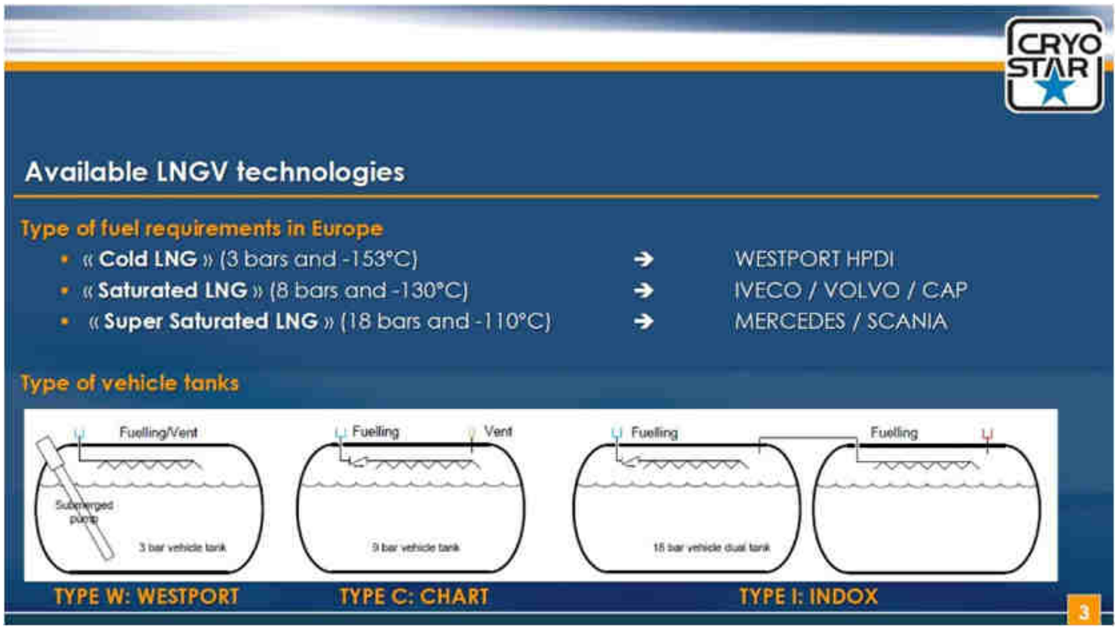


Fig 2-3 some examples of LNG service pressures [source: CRYO STAR]

Another important parameter is the way of handling boil-off. No vessel can be perfectly adiabatic; let alone cryogenic vessels. The large temperature difference between inside and outside of the tank is always carrying energy through the walls, despite their high thermal insulation. The modern storage tanks have double wall structure, with vacuum between walls, and super insulating layers above outer wall. This prevents large amounts of heat to flow in. Only a limited quantity of heat can flow across the walls of the tanks. Over the time, this heat is anyway sufficient to increase the temperature of liquid contained in the tank, until the liquid reaches the boiling point at the existing service pressure (the boiling points at different pressures are shown by the saturation curve in *Fig 2-4*). At this point, as the LNG vapor cannot leave the tank, also the pressure starts to increase. If there is a regular substitution rate of LNG, by extraction of product to refuel vehicles, and replacement of it with new cold LNG, the proper conditions of pressure and temperature are kept inside the tank. If no sufficient product replacement is done this way, the temperature and pressure inside the tank increase up to the maximum design level. The tank is protected against overpressure by PRV (pressure release valve) which at this point actuates at a set pressure level, venting part of gas until the proper pressure is reseated. This gas is normally called boil-off gas, and the issue is named boil-off. This situation is required for safety, but it is not acceptable from the point of view of environment and economy, as precious fuel is potentially supposed to be wasted or flared, thus contributing to the greenhouse effect. For this reason, if this situation is expected to occur during the operation of the service station, the design of the station must include some means of recovering the boil-off gas. It can be done e.g. by means of a compressor, turning the boil-off gas into CNG and selling it as such at a CNG dispenser in the station. Otherwise, as just another example, it can be done by means of a small refrigeration unit, to turn it back into LNG, and send it back to tank. The refrigeration unit can be either based on compression, or liquid nitrogen. The first case (CNG), offers all the already seen advantages of the L-CNG solution. The second case (back to LNG), is in general more expensive, and it is not in common application.

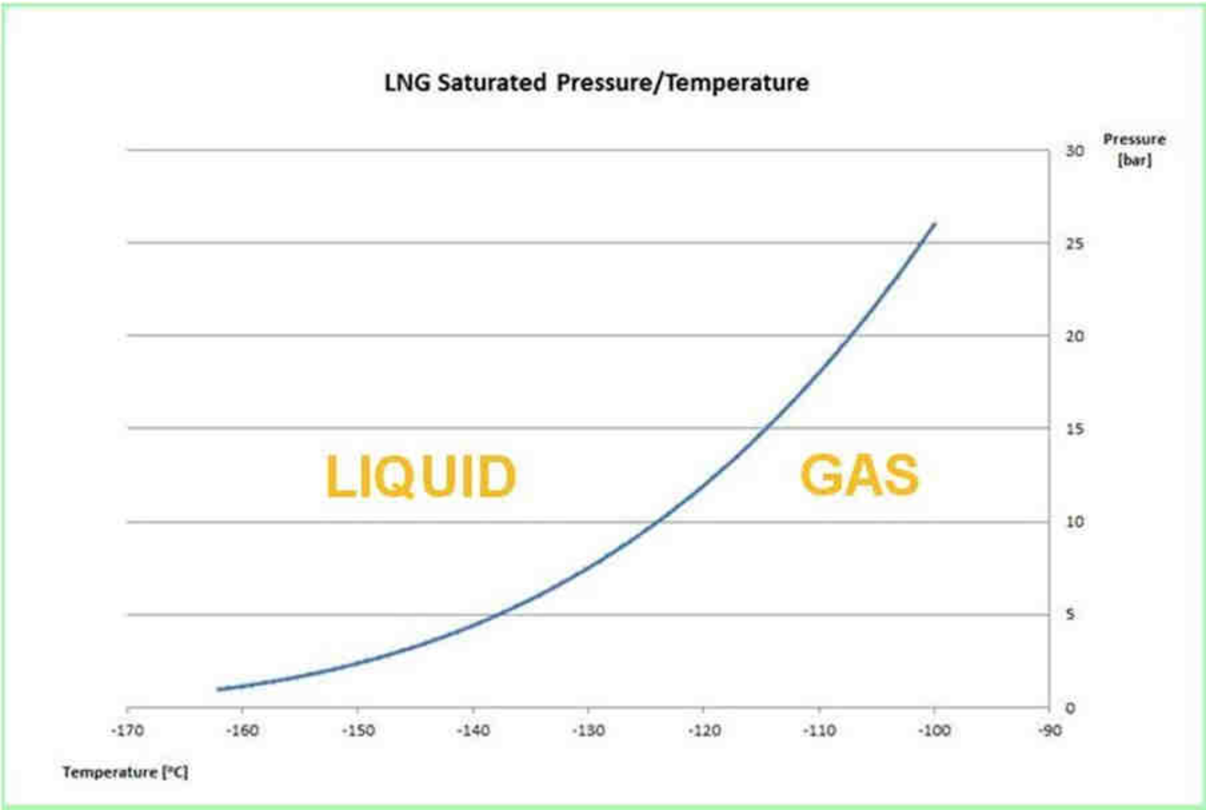


Fig 2-4 boiling temperatures versus pressure

The service pressure of the station has some influence on the system adopted for LNG transfer from station tank to vehicle tank. This can be done either by means of pressure differential, or centrifugal low pressure pump. In case of pressure differential, the dispenser needs to be within a maximum distance from the station tank. If the connecting pipe is too long, the dynamic resistance to liquid flow along the pipe will tend to cause too large pressure drop, and resulting flow restrictions, devices malfunction, and difficulty in the refueling process. With the pump this distance can be longer.

2.2 The L-CNG operation

The L-CNG system makes use of the LNG "compression", (or better, pressurization) of natural gas in liquid phase with cryogenic pumps that raise the pressure up to values of 300 bar. The LNG in these conditions is then sent to an atmospheric heat exchanger, which takes heat from ambient air, to make LNG to evaporate. The temperature level of the ambient air, as "hot spring" is always adequate, even in winter and at higher latitudes, because a robust differential temperature is always available between air and LNG at -160 ° C. Once it is at the state of CNG, the natural gas is stored in banks of cylinders that serve as storage, or can be sent directly to the dispenser, for the refueling of the vehicle.

2.3 Main components of the LNG station

Cryogenic LNG tank (PED / ADP):

It is normally a super-insulated, vacuum-separated two-wall vessel. It receives LNG from the tanker truck, and delivers it to the station dispensers under request of the customer, as L-CNG HD and LD vehicles) and LNG (HD vehicles).

- Typical capacity: from 5 to 130 m^3 (it is the "water capacity", i.e. internal geometric volume available for LNG; one m^3 contains about half ton of LNG; for safety reasons, the tank can be filled up to 95% of water capacity)
- Pressure from 5 to 15 bar
- Inner tank in stainless steel; outer tank wall can be in different metals
- Perlite insulation (rock) + vacuum
- Flowmeter Mass (Coriolis)
- Supply connector: Parker and Kodiak

Cryogenic high pressure LNG pump

It takes low pressure LNG from the station tank, and pump it up to 200 – 250 bar to a heat exchanger, thus producing CNG.

- Typical flow rate: 17-20 l/min
- Max discharge pressure: 350 bar
- Typical suction pressure: 5-15 bar
- Typical impeller speed: 450 r/min
- Example of electric motor: 30 kW power Ex d II T4 (4-pin) - power supply 400 V - 50 Hz

Electrical control panel

The electrical control panel automatically controls the station through receiving signals in a continuous manner by the various transducers in the field:

- Pressure in the cryogenic tank of the station
- Level of liquid in the cryogenic tank
- Temperature of LNG
- Temperature of cooling circuit
- Temperature detector of the cold gas
- Pressure in the line
- Delivery pressure of gas (LNG)

The electrical panel, according to safety standards, must be installed in a safe area, so it is the only element that is not installed on the system platform.

Atmospheric LNG vaporizer (in case of L-CNG station)

It takes 200-250 bar LNG from the high-pressure pump and vaporizes it, generally by use of ambient air heat, to deliver CNG at its output.

- Typical flow rate: 400-600 Nm^3/h
- Maximum working pressure: 420 bar
- Piping: AISI 304L Ø 16 mm x 2.5 mm
- Odorisation system

Cryogenic low pressure pump

It can be used to transfer LNG from the station tank to the vehicle tank during refuelling of HD LNG vehicles.

- Typical flow rate: 700-800 kg/min
- Maximum working pressure: 34 bar
- Typical power: 16 kWh

Sometimes, depending on the station design, it is possible to avoid the use of this component, by adopting a high LNG station tank, (15 – 20 metres high above ground level), and an appropriate LNG conditioner (heat exchanger), which allows a sufficiently high flow rate of LNG by simple pressure and level difference between station tank and vehicle tank. Avoiding this low-pressure pump allows some energy and Capex saving. In particular the main advantage offered by a low-pressure pump free dispenser are:

- Lower Capex: typically some thousands euro saved
- No need for an electronic control panel
- No energy required for liquid transfer
- No need to refrigerate the pump (weight about 150 kg) before each filling operation
- No additional heat transfer to LNG in the tank (which applies in case of submerged pump)
- Lower number of potential leak sources
- Simpler layout

Fig 2-5 cryogenic pumps [source: Vanzetti]

2.4 LNG technology options

The main examples of LNG technologies under examination in the LNG Blue Corridors Project are:

- Technology **A**: saturated LNG at 7-8 bar
- Technology **AM**: Technology A, mobile type
- Technology **B**: saturated LNG and CNG (L-CNG)
- Technology **C**: super saturated (18 bar) and saturated LNG
- Technology **D**: super saturated and saturated LNG and CNG (L-CNG)
- Technology **DM**: Technology D, mobile type

A summary of advantages and limitations of each technology is shown in the table below, irrespective of their manufacturers:

Tab 2-1 advantages and limitations of each technology

technology	Working principle	limitations	advantages
A: saturated LNG at 7-8 bar	Differential pressure	Only "low pressure" trucks No CNG delivery No boil-off recovery Low refueling rate Custom design	Relatively Low CAPEX Relatively Low OPEX Low space requirements High reliability

AM: Technology A, mobile type	Differential pressure Mobile	Only "low pressure" trucks No CNG delivery Not boil-off recovery Low refueling rate Custom design	Relatively Low CAPEX Relatively Low OPEX Low space requirements High reliability Flexibility Approvals
B: saturated LNG and CNG (L-CNG)	Differential pressure Boil-off recovery with compressor	Only "low" pressure trucks LNG Dispenser cannot be allocated far away from tank Moderate operational costs	Medium CAPEX Low space requirements High reliably supply to CNG vehicles Doesn't require a minimum number of LNG trucks.
C: super saturated (18 bar) and saturated LNG	Centrifugal pump	Moderate-high investment cost Moderate operational cost No boil-off recovery No CNG	Possibility to refuel all kinds of LNG trucks LNG dispenser doesn't need to be nearby the storage tank. High LNG refueling capacity.
D: super saturated and saturated LNG and CNG (L-CNG)	Centrifugal pump Piston pump Boil-off recovery	High investment cost High operational cost	Possibility to refuel all kinds of LNG trucks LNG dispenser doesn't needs to be nearby the storage tank. High LNG refueling capacity (several dispensers can be served at same time) High CNG refueling capacity Doesn't require a minimum number of LNG trucks, regarding an acceptable number of CNG LV clients are available.
DM: Technology D,	Centrifugal pump	No boil-off recovery	Possibility to refuel all kinds of LNG trucks

mobile type	Piston pump		LNG dispenser doesn't need to be nearby the storage tank. Low capital and operational costs. Low space requirements. Flexibility due the mobile concept. CNG refueling capacity. Doesn't require a minimum number of LNG trucks.

3 Types of costs

For this analysis, estimated and real costs have been taken into account for stationary refueling stations, based on reports of the owners and manufacturers of LNG refueling stations that are partners of the LNG BC Project. Estimated costs have been considered for mobile stations.

It must be taken in consideration that some items, e.g. civil works, are specific for each station depending on the conditions of the site where the station is built.

However, and assuming that the civil works costs cannot be applied on any station (in each station will be different), other costs derived from built stations have been taken as a general reference. The application of LNG to the NGV sector is relatively young in Europe, and extensive data are not yet commonly in reach. In some cases, where actual data were not available, some logical extrapolations have been done.

3.1 Common costs

There are some common items in the projects and construction of the LNG refueling stations, which are neither location nor technology dependent, so these costs are similar in the various different technologies:

- Scope of works and services
    - Development cost
    - Engineering
    - Project Management
    - Mobilization cost
    - External auxiliary equipment
- Electricity and Control
    - Remote control system
    - Payment system
- Auxiliary facilities
    - Vents and drainages
    - Compressed air
    - Firefighting facilities
    - Property security
    - Corporate image

The cost for field acquisition is not included in the analysis. It is too variable depending on country, location, vicinity to urban areas, original destination of land in the local municipal planning, and other parameters. The main aspect affecting this type of cost is the choice between two basic options:

- Construction from scratch of a brand new refuelling station, mono or multi-fuel, selling LNG (likely also L-CNG) side by side with one or more of the other fuels: gasoline, diesel, LPG, biomethane, hydrogen. Or total remake of an old existing multi-fuel station and installation of additional LNG plants in the same conditions as above.

- Installation of an LNG plant and dispenser into an already existing multi-fuel refueling station, which has a sufficient amount of spare space available inside and around its premises, also taking in account the applicable regulatory safety distances in the country.

The general coordinated look of the station will be usually better with the first choice.

The second is the best choice in some other respects. It has access to some existing features and can count on existing operating personnel, after the due training, so it is usually cheaper both as CAPEX and OPEX. It must face the financial, contractual and fiscal aspect of relationship between the owner/operator of the existing station and that of the added plant, if it is not the same.

In most circumstances, the field cost is not at all negligible, and it must be taken in consideration as an unpredictable item on top of the cost analysis.

Also the costs of licenses and permits are stipulated from local governments. Therefore, they can be different depending on the location.

3.2 Variable costs

There are many costs which are associated with the technology used, so they are different for each type of station:

- Earthworks
  - Civil works
  - Structures
- LNG storage
  - Vessel storage
  - Offloading system
- LNG system
  - LNG pumping
  - LNG conditioning system
- CNG system
  - Boil off management
  - Pressure regulation
  - Odorization
  - Compression
  - Storage

- Dispensers
    - LNG
    - CNG
- Utilities
    - Electrical supply installations to the station
    - Water supply and drainage

Generally the considered costs include equipment acquisition, its transport and assembling on the site.

The number of LNG refueling stations in Europe is still limited, so even if the analysis is necessarily based on a limited ground and experience coming from the stations built in the Project, this can be considered representative enough of the LNG sector in Europe. The number is sufficient anyway to make an assessment reasonably dependable, while bearing in mind that in Europe this field is still at a pioneering stage. An effort has been done to extract the most generic figures as possible, even if some of the figures are necessarily related to some actual non repeatable experience on field.

The LNG tank is one of the main constituents of both L-CNG an LNG refuelling stations. The capacity of the LNG tank must be chosen to the best compromise between cost and time between filling by road tanker. The typical capacity examined are: 20 m^3, 30 m^3 and 60 m^3, even if larger capacity tanks are also adopted. The range of tanks on the market is from 5 to 130 m^3.

The cost of this component, in the range from 20 to 60 m^3, varies between 95.000 and 135.000 €. The increase of cost is of course proportional to capacity, but not in a linear way, and a relative scale effect is available here, on the mere cost of component. Furthermore, the larger the tank, the longer the residence time in case of no use, due to increasing volume vs. surface ratio. This reflects on some operational cost, such as re-liquefaction of boil-off gas, or compression to turn it into CNG. Also the frequency of filling by road tanker benefits from larger capacities. In general, the road tankers have a capacity of 45 to 55 m^3. On the one hand, these features are generally orienting the operator’s choice towards larger capacity tanks, except in very marginal areas, where a substantial served fleet of LNG trucks is not expected shortly, and at the same time there is not a CNG market to provide additional income. On the other hand, too large capacity tanks might face problems on the side of:

- Authority approval of project, which might be influenced by the amount of energy stored,
- Possible local regulation limitations,
- architectural affect, especially in case of vertical tank,
- negative reaction of local population, due to exaggerate perception of risk,
- cost of the support structure, and of the containment concrete sink, if required by the European, local or adopted regulation,
- cost of transport to the site, as it’s a special transport.

3.3 Common costs of stationary LNG stations

A fully detailed analysis of the construction costs has been made for the stations, depending on different technologies (Manufacturer M1). It is based on a first scheme of costs which are common to all the examined technologies, and on a subsequent scheme of the costs which are variable with the reference technology. A more condensed analysis of the costs is shown for all the other refuelling stations which are not included in this first set of tables, further on in the document.

Tab 3-1 Common costs of stationary stations (Manufacturer M1)

Cod	Item	unit	Price €	amount	Final cost €
1.	**SCOPE OF WORK AND SERVICES**				38.000
1.1	**ENGINEERING AND PROCEDURES**				38.000
1.1.1	Engineering		38.000,00	1	38.000
1.1.2	Documentation				
1.1.3	Administrative procedures				
1.1.4	Projects autorization				
1.1.5	Emergency plan				
1.1.6	Licenses and fees payment	Not included			
2.	**ELECTRIC SYSTEM, CONTROL & TELECOMAND**				106.240
2.1	**ELECTRIC SYSTEM**				92.100
2.1.1	Connection point for low voltage		3.000	1	3.000
2.1.2	Metering and protection for low voltage		950	1	950
2.1.3	Connection point for medium voltage (240 Kva)		66.650	1	66.650
2.1.4	Complete electric facilities		20.000	1	20.000
2.1.5	Additional cost for distance from containment >25m	m	100	1	100
2.1.6	Additional cost for low voltage metering		1.200	1	1.200
2.1.7	General lighting		200	1	200
2.2	**CONTROL SYSTEM**				6.500
2.2.1	Complete control system		4.500	1	4.500

2.2.2	Additional cost for distance from containment >25m	m	100	20	2.000
2.3	**TELECOMAND**				640
2.3.1	Station connection to control center of maintainer		400	1	400
2.3.2	Gas supplier access to data of the station		120	1	120
2.3.3	Link installation gas supplier control center-station		120	1	120
2.4	**PAYMENT SYSTEM**				7.000
2.4.1	Installation point of payment approved and supplied by gas supplier		500	1	500
2.4.2	Installation point of payment approved and supplied by bidder		5.500	1	5.500
2.4.3	Communication equipment and wiring		1.000	1	1.000
3.	**AUXILIARY FACILITIES**				26.400
3.1	**VENTS AND DRAINAGE GRIDS**				7.300
3.1.1	Vents and drainages		2.500	1	2.500
3.1.2	Vents grid (blowdown)		2.000	1	2.000
3.1.3	Drainages grid		1.500	1	1.500
3.1.4	Drainage storage		1.300	1	1.300
3.2	**COMPRESSED AIR**				8.800
3.2.1	Compressed air station		5.800	1	5.800
3.2.2	Compressed air grid		1.000	1	1.000
3.2.3	Additional cost for distance from containment >25m	m	100	20	2.000
3.3	**FIREFIGHTING FACILITIES**				3.500
3.3.	Firefighting equipment and signaling		1.500	1	1.500

1					
3.3.2	Gas detectors		2.000	1	2.000
3.4	**PROPERTY SECURITY**				3.500
3.4.1	Pipes for the installation of technical protection means. Facility level I		1.500	1	1.500
3.4.2	Pipes for the installation of technical protection means. Facility level II		2.000	1	2.000
3.5	**WATER FOR SERVICES**				3.300
3.5.1	Water grid for services		1.300	1	1.300
3.5.2	Storage of water for services with pump		2.000	1	2.000
	GRAND TOTAL				**170.000**

3.4 Variable costs of stationary LNG stations

Tab 3-2 Specific costs for technology A: saturated LNG at 7-8 bar (Manufacturer M1)

Cod	Item	Un.	price	Am.	Final cost
2. CIVIL WORKS AND STRUCTURES					**71.675**
2.1 CIVIL WORKS					62.000
2.1.1	Land purchase	Not included			
2.1.2	Earthworks (existing station)	m	170,00	25	4.250
2.1.3	Earthworks (green field). Clearing	m	190,00	25	4.750
2.1.4	Earthworks (green field). Digging	m	190,00	25	4.750
2.1.5	Earthworks (green field). Grading and levelling	m	190,00	25	4.750
2.1.6	Access to the plot	m	350,00	10	3.500
2.1.7	Vials (paths)	m	350,00	10	3.500
2.1.8	Perimeter fencing	m	120,00	10	1.200
2.1.9	Perimeter fencing – pedestrian door		400,00	10	4.000

2.1.10	Perimeter fencing – vehicle door		1.000,00	10	10.000
2.1.11	Equipment foundations		1.300,00	1	1.300
2.1.12	Containment		18.000,00	1	18.000
2.1.13	Islet suppliers not installed on the perimeter of the containment	m^2	190,00	0	0
2.1.14	Transformer foundation		2.000,00	1	2.000
2.2 STRUCTURES					9.675
2.2.1	Small canopy for LNG & CNG dispensers. Lighting included		2.000,00	1	2.000
2.2.2	Medium canopy for compressor modules – CNG dispens. Lighting incl.		3.325,00	0	0
2.2.3	General lighting		1.600,00	1	1.600
2.2.4	Work shed for electric and control panels		5.700,00	1	5.700
2.2.5	Defences		375,00	1	375
2.2.6	Corporate image	Not included			
3. LNG STORAGE					**155.000**
3.1 LNG VESSEL					135.000
3.1.1	LNG vessel 20 m^3, service pressure < 14 bar		95.000,00	0	0
3.1.2	LNG vessel 30 m^3, service pressure < 14 bar		115.000,00	0	0
3.1.3	LNG vessel 60 m^3, service pressure < 14 bar		135.000,00	1	135.000
3.2 TANK OFFLOADING					20.000
3.2.1	Cryogenic hose		20.000,00	1	20.000
4. LNG SYSTEM					**8.500**
4.1 CENTRIFUGAL PUMP					
4.1.1	Submerged cryogenic centrifugal pump		55.000,00	0	0
4.2 LNG CONDITIONERS					8.500
4.2.1	Conditioners in line		8.500,00	1	8.500
5. CNG SYSTEM					
5.1 BOIL-OFF RECOVERY MODULE					

5.1.1	Economizer valve, atmospheric vaporizer & automatic cold cut. Valve		22.000,00	0	0
5.1.2	Additional atmospheric vaporizer		4.250,00	0	0
5.2 REGULATION UNIT					
5.2.1	Regulation unit		25.000,00	0	0
5.3 LOW PRESSURE ODORISER MODULE					
5.3.1	Low pressure odoriser module (<20 bar) – 25 litres		2.375,00	0	0
5.3.2	Low pressure odoriser module (<20 bar) – 50 litres		2.950,00	0	0
5.3.3	Remote signals of low THT level		450,00	0	0
5.4 INTEGRAL MODULE COMPRESSOR - DISPENSER					
5.4.1	Integ. module compressor-dispenser, 300 Nm^3/h, storage >500 l; 1 hose		135.000,00	0	0
5.4.2	Integ. module compressor-dispenser, 300 Nm^3/h, storage >500 l; 2 hoses		140.000,00	0	0
5.4.3	Extra-cost of supplying RF-120 cabin		5.500,00	0	0
5.4.4	Extra-cost of supplying sound reduction cabin until 45 Db(A) at 10 m		8.500,00	0	0
5.4.5	Extra-cost of supplying blast-resistant cabin		7.000,00	0	0
5.5 CNG SYSTEM FOR FUTURE EXTENTIONS					
5.5.1	PISTON PUNPS + ATMOSPHERIC VAPORIZERS				
5.5.1.1	Cryogenic pistons pump for rates of 400 Nm^3/h Q= 11,6 l/m		40.000,00	0	0
5.5.1.2	Atmospheric vaporizer of 400 Nm^3/h		14.000,00	0	0
5.5.1.3	Cryogenic pistons pump for rates of 800 Nm^3/h Q= 20 l/m		50.000,00	0	0
5.5.1.4	Atmospheric vaporizer of 800 Nm^3/h		15.000,00	0	0
5.5.1.5	Cryogenic pistons pump for rates of 1.200 Nm^3/h Q= 34 l/m		60.000,00	0	0
5.5.1.6	Atmospheric vaporizer of 1.200 Nm^3/h		16.000,00	0	0
5.5.2	BOIL-OFF RECOVERY MODULE				

5.5.2.1	Horizontal vessel		70.000,00	0	0
5.5.2.2	Reciprocating compressor		20.000,00	0	0
5.5.3	HIGH PRESSURE ODORISER MODULE		8.550,00	0	0
5.5.3.1	High pressure odoriser module(250 bar)				
5.6 CNG STORAGE MODULE					
5.6.1	External storage bottle rack, capacity 720 litres		8.000,00	0	0
5.6.2	External storage bottle rack, capacity 1.200 litres		14.000,00	0	0
5.6.3	Canopy for rack, capacity 720 litres		475,00	0	0
5.6.4	Canopy for rack, capacity 720 litres		700,00	0	0
6. DISPENSERS					**48.643**
6.1 LNG DISPENSERS					48.643
6.1.1	Saturated LNG dispenser, 8 bar; -130°C; 1 supply point		35.000,00	1	35.000
6.1.2	Gas return flowmeter		3.500,00	1	3.500
6.1.3	Pocket nozzle heating		1.350,00	1	1.350
6.1.4	Automatic system for nozzle cleaning by compressor air		1.000,00	1	1.000
6.1.5	(INDOX) Return hose 1" with J.C. Carter connection		7.793,00	1	7.793
6.2 CNG DISPENSERS					
6.2.1	CNG dispenser, 200 bar; 15° C; 1 supply point		23.000,00	0	0
6.2.2	CNG dispenser, 200 bar; 15° C; 2 supply points		28.000,00	0	0
6.2.3	Additional cost for distance from containment > 25 m	m	100,00	0	0
TOTAL – Technology A: saturated LNG at 7-8 bar					**283.818**

Tab 3-3 Specific costs for technology B: saturated LNG and CNG (L-CNG) (Manufacturer M1)

Cod	Item	Un.	price	Am.	Final cost
2. CIVIL WORKS AND STRUCTURES					**75.190**
2.1 CIVIL WORKS					62.190

2.1.1	Land purchase	Not included			
2.1.2	Earthworks (existing station)	m	170,00	25	4.250
2.1.3	Earthworks (green field). Clearing	m	190,00	25	4.750
2.1.4	Earthworks (green field). Digging	m	190,00	25	4.750
2.1.5	Earthworks (green field). Grading and levelling	m	190,00	25	4.750
2.1.6	Access to the plot	m	350,00	10	3.500
2.1.7	Vials	m	350,00	10	3.500
2.1.8	Perimeter fencing	m	120,00	10	1.200
2.1.9	Perimeter fencing – pedestrian door		400,00	10	4.000
2.1.10	Perimeter fencing – vehicle door		1.000,00	10	10.000
2.1.11	Equipment foundations		1.300,00	1	1.300
2.1.12	Containment		18.000,00	1	18.000
2.1.13	Islet suppliers not installed on the perimeter of the containment	m^2	190,00	1	190
2.1.14	Transformer foundation		2.000,00	1	2.000
2.2 STRUCTURES					13.000
2.2.1	Small canopy for LNG & CNG dispensers. Lighting included		2.000,00	1	2.000
2.2.2	Medium canopy for compressor modules – CNG dispenser. Lighting incl.		3.325,00	1	3.325
2.2.3	General lighting		1.600,00	1	1.600
2.2.4	Work shed for electric and control panels		5.700,00	1	5.700
2.2.5	Defences		375,00	1	375
2.2.6	Corporate image				
3. LNG STORAGE					**155.000**
3.1 LNG VESSEL					135.000
3.1.1	LNG vessel 20 m^3, service pressure < 14 bar		95.000,00		
3.1.2	LNG vessel 30 m^3, service pressure < 14 bar		115.000,00		
3.1.3	LNG vessel 60 m^3, service pressure < 14 bar		135.000,00	1	135.000

3.2 TANK OFFLOADING					20.000
3.2.1	Cryogenic hose		20.000,00	1	20.000
4. LNG SYSTEM					**8.500**
4.1 CENTRIFUGAL PUMP					
4.1.1	Submerged cryogenic centrifugal pump		55.000,00		
4.2 LNG CONDITIONERS					8.500
4.2.1	Conditioners in line		8.500,00	1	8.500
5. CNG SYSTEM					**393.950**
5.1 BOIL-OFF RECOVERY MODULE					26.250
5.1.1	Economizer valve, atmospheric vaporizer & automatic cold cutting valve		22.000,00	1	22.000
5.1.2	Additional atmospheric vaporizer		4.250,00	1	4.250
5.2 REGULATION UNIT					25.000
5.2.1	Regulation unit		25.000,00	1	25.000
5.3 LOW PRESSURE ODORISER MODULE					450
5.3.1	Low pressure odoriser module (<20 bar) – 25 litres		2.375,00		
5.3.2	Low pressure odoriser module (<20 bar) – 50 litres		2.950,00		
5.3.3	Remote signals of low THT level		450,00	1	450
5.4 INTEGRAL MODULE COMPRESSOR - DISPENSER					156.000
5.4.1	Integ. mod. compressor-dispenser, 300 Nm^3/h, storage >500 l; 1 hose		135.000,00	1	135.000
5.4.2	Integ. mod. compressor-dispenser, 300 Nm^3/h, storage >500 l; 2 hoses		140.000,00		
5.4.3	Extra-cost of supplying RF-120 cabin		5.500,00	1	5.500
5.4.4	Extra-cost of supplying sound reduction cabin until 45 Db(A) at 10 m		8.500,00	1	8.500
5.4.5	Extra-cost of supplying blast-resistant cabin		7.000,00	1	7.000
5.5 CNG SYSTEM FOR FUTURE EXTENTIONS					163.550
5.5.1	PISTON PUMPS + ATMOSPHERIC VAPORIZERS				65.000

5.5.1.1	Cryogenic pistons pump for rates of 400 Nm^3/h Q= 11,6 l/m		40.000,00		
5.5.1.2	Atmospheric vaporizer of 400 Nm^3/h		14.000,00		
5.5.1.3	Cryogenic pistons pump for rates of 800 Nm^3/h Q= 20 l/m		50.000,00	1	50.000
5.5.1.4	Atmospheric vaporizer of 800 Nm^3/h		15.000,00	1	15.000
5.5.1.5	Cryogenic pistons pump for rates of 1.200 Nm^3/h Q= 34 l/m		60.000,00		
5.5.1.6	Atmospheric vaporizer of 1.200 Nm^3/h		16.000,00		
5.5.2	BOIL-OFF RECOVERY MODULE				90.000
5.5.2.1	Horizontal vessel		70.000,00	1	70.000
5.5.2.2	Reciprocating compressor		20.000,00	1	20.000
5.5.3	HIGH PRESSURE ODORISER MODULE				8.550
5.5.3.1	High pressure odoriser module(250 bar)		8.550,00	1	8.550
5.6 CNG STORAGE MODULE					22.700
5.6.1	External storage bottle rack, capacity 720 litres		8.000,00	1	8.000
5.6.2	External storage bottle rack, capacity 1.200 litres		14.000,00	1	14.000
5.6.3	Canopy for rack, capacity 720 litres		475,00		
5.6.4	Canopy for rack, capacity 720 litres		700,00	1	700
6. DISPENSERS					**48.643**
6.1 LNG DISPENSERS					48.643
6.1.1	Saturated LNG dispenser, 8 bar; -130°C; 1 supply point		35.000,00	1	35.000
6.1.2	Gas return flowmeter		3.500,00	1	3.500
6.1.3	Pocket nozzle heating		1.350,00	1	1.350
6.1.4	Automatic system for nozzle cleaning by compressor air		1.000,00	1	1.000
6.1.5	(INDOX) Return hose 1” with J.C. Carter connection		7.793,00	1	7.793
6.2 CNG DISPENSERS					28.000
6.2.1	CNG dispenser, 200 bar; 15° C; 1 supply point		23.000,00		
6.2.2	CNG dispenser, 200 bar; 15° C; 2 supply points		28.000,00	1	28.000
6.2.3	Additional cost for distance from containment > 25 m	m	100,00		

TOTAL - Technology B: saturated LNG and CNG (L-CNG)				681.283

Tab 3-4 Specific costs for technology C: super saturated (18 bar) and saturated LNG (Manufacturer M1)

Cod	Item	Un.	price	Am.	Final cost
2. CIVIL WORKS AND STRUCTURES					**71.675**
2.1 CIVIL WORKS					62.000
2.1.1	Land purchase	Not included			
2.1.2	Earthworks (existing station)	m	170,00	25	4.250
2.1.3	Earthworks (green field). Clearing	m	190,00	25	4.750
2.1.4	Earthworks (green field). Digging	m	190,00	25	4.750
2.1.5	Earthworks (green field). Grading and levelling	m	190,00	25	4.750
2.1.6	Access to the plot	m	350,00	10	3.500
2.1.7	Vials	m	350,00	10	3.500
2.1.8	Perimeter fencing	m	120,00	10	1.200
2.1.9	Perimeter fencing – pedestrian door		400,00	10	4.000
2.1.10	Perimeter fencing – vehicle door		1.000,00	10	10.000
2.1.11	Equipment foundations		1.300,00	1	1.300
2.1.12	Containment		18.000,00	1	18.000
2.1.13	Islet suppliers not installed on the perimeter of the containment	m^2	190,00		
2.1.14	Transformer foundation		2.000,00	1	2.000
2.2 STRUCTURES					9.675
2.2.1	Small canopy for LNG & CNG dispensers. Lighting included		2.000,00	1	2.000
2.2.2	Medium canopy for compressor modules – CNG dispenser. Lighting incl.		3.325,00		
2.2.3	General lighting		1.600,00	1	1.600
2.2.4	Work shed for electric and control panels		5.700,00	1	5.700
2.2.5	Defences		375,00	1	375

2.2.6	Corporate image				
3. LNG STORAGE					**155.000**
3.1 LNG VESSEL					135.000
3.1.1	LNG vessel 20 m^3, service pressure < 14 bar		95.000,00		
3.1.2	LNG vessel 30 m^3, service pressure < 14 bar		115.000,0 0		
3.1.3	LNG vessel 60 m^3, service pressure < 14 bar		135.000,0 0	1	135.000
3.2 TANK OFFLOADING					20.000
3.2.1	Cryogenic hose		20.000,00		20.000
4. LNG SYSTEM					**63.500**
4.1 CENTRIFUGAL PUMP					55.000
4.1.1	Submerged cryogenic centrifugal pump		55.000,00		55.000
4.2 LNG CONDITIONERS					8.500
4.2.1	Conditioners in line				8.500
5. CNG SYSTEM					
5.1 BOIL-OFF RECOVERY MODULE					
5.1.1	Economizer valve, atmospheric vaporizer & automatic cold cutting valve		22.000,00		
5.1.2	Additional atmospheric vaporizer		4.250,00		
5.2 REGULATION UNIT					
5.2.1	Regulation unit		25.000,00	1	
5.3 LOW PRESSURE ODORISER MODULE					
5.3.1	Low pressure odoriser module (<20 bar) – 25 litres		2.735,00		
5.3.2	Low pressure odoriser module (<20 bar) – 50 litres		2.950,00	1	
5.3.3	Remote signals of low THT level		450,00		
5.4 INTEGRAL MODULE COMPRESSOR - DISPENSER					
5.4.1	Integ. module compressor-dispenser, 300 Nm^3/h, storage >500 l; 1 hose		135.000,0 0		

5.4.2	Integ. module compressor-dispenser ,300 Nm^3/h, storage >500 l; 2 hoses		140.000,00		
5.4.3	Extra-cost of supplying RF-120 cabin		5.500,00		
5.4.4	Extra-cost of supplying sound reduction cabin until 45 Db(A) at 10 m		8.500,00		
5.4.5	Extra-cost of supplying blast-resistant cabin		7.000,00		
5.5 CNG SYSTEM FOR FUTURE EXTENTIONS					
5.5.1	PISTON PUNPS + ATMOSPHERIC VAPORIZERS				
5.5.1.1	Cryogenic pistons pump for rates of 400 Nm^3/h Q= 11,6 l/m		40.000,00		
5.5.1.2	Atmospheric vaporizer of 400 Nm^3/h		14.000,00		
5.5.1.3	Cryogenic pistons pump for rates of 800 Nm^3/h Q= 20 l/m		50.000,00		
5.5.1.4	Atmospheric vaporizer of 800 Nm^3/h		15.000,00		
5.5.1.5	Cryogenic pistons pump for rates of 1.200 Nm^3/h Q= 34 l/m		60.000,00		
5.5.1.6	Atmospheric vaporizer of 1.200 Nm^3/h		16.000,00		
5.5.2	BOIL-OFF RECOVERY MODULE				
5.5.2.1	Horizontal vessel		70.000,00		
5.5.2.2	Reciprocating compressor		20.000,00		
5.5.3	HIGH PRESSURE ODORISER MODULE				
5.5.3.1	High pressure odoriser module(250 bar)		8.550,00		
5.6 CNG STORAGE MODULE					
5.6.1	External storage bottle rack, capacity 720 litres		8.000,00		
5.6.2	External storage bottle rack, capacity 1.200 litres		14.000,00		
5.6.3	Canopy for rack, capacity 720 litres		475,00		
5.6.4	Canopy for rack, capacity 720 litres		700,00		
6. DISPENSERS					83.643

6.1 LNG DISPENSERS					83.643
6.1.1	Saturated LNG dispenser, 8 bar; -130°C; 1 supply point		35.000,00	2	70.000
6.1.2	Gas return flowmeter		3.500,00	1	3.500
6.1.3	Pocket nozzle heating		1.350,00	1	1.350
6.1.4	Automatic system for nozzle cleaning by compressor air		1.000,00	1	1.000
6.1.5	(INDOX) Return hose 1" with J.C. Carter connection		7.793,00	1	7.793
6.2 CNG DISPENSERS					
6.2.1	CNG dispenser, 200 bar; 15° C; 1 supply point		23.000,00		
6.2.2	CNG dispenser, 200 bar; 15° C; 2 supply points		28.000,00		
6.2.3	Additional cost for distance from containment > 25 m	m	100,00		
TOTAL - Technology C: super saturated (18 bar) and saturated LNG					**373.818**

Tab 3-5 Specific costs for technology D: super saturated and saturated LNG and CNG (L-CNG) (Manufacturer M1)

Cod	Item	Un.	price	Am.	Final cost
2. CIVIL WORKS AND STRUCTURES					**75.190**
2.1 CIVIL WORKS					62.190
2.1.1	Land purchase	Not included			
2.1.2	Earthworks (existing station)	m	170,00	25	4.250
2.1.3	Earthworks (green field). Clearing	m	190,00	25	4.750
2.1.4	Earthworks (green field). Digging	m	190,00	25	4.750
2.1.5	Earthworks (green field). Grading and levelling	m	190,00	25	4.750
2.1.6	Access to the plot	m	350,00	10	3.500
2.1.7	Vials	m	350,00	10	3.500
2.1.8	Perimeter fencing	m	120,00	10	1.200
2.1.9	Perimeter fencing – pedestrian door		400,00	10	4.000
2.1.10	Perimeter fencing – vehicle door		1.000,00	10	10.000
2.1.11	Equipment foundations		1.300,00	1	1.300

2.1.12	Containment		18.000,00	1	18.000
2.1.13	Islet suppliers not installed on the perimeter of the containment	m^2	190,00	1	190
2.1.14	Transformer foundation		2.000,00	1	2.000
2.2 STRUCTURES					13.000
2.2.1	Small canopy for LNG & CNG dispensers. Lighting included		2.000,00	1	2.000
2.2.2	Medium canopy for compressor modules – CNG dispenser. Lighting incl.		3.325,00	1	3.325
2.2.3	General lighting		1.600,00	1	1.600
2.2.4	Work shed for electric and control panels		5.700,00	1	5.700
2.2.5	Defences		375,00	1	375
2.2.6	Corporate image	Not included			
3. LNG STORAGE					**155.000**
3.1 LNG VESSEL					135.000
3.1.1	LNG vessel 20 m^3, service pressure < 14 bar		95.000,00		
3.1.2	LNG vessel 30 m^3, service pressure < 14 bar		115.000,00		
3.1.3	LNG vessel 60 m^3, service pressure < 14 bar		135.000,00	1	135.000
3.2 TANK OFFLOADING					20.000
3.2.1	Cryogenic hose		20.000,00	1	20.000
4. LNG SYSTEM					**63.500**
4.1 CENTRIFUGAL PUMP					55.000
4.1.1	Submerged cryogenic centrifugal pump		55.000,00	1	55.000
4.2 LNG CONDITIONERS					8.500
4.2.1	Conditioners in line		8.500,00	1	8.500
5. CNG SYSTEM					**393.950**
5.1 BOIL-OFF RECOVERY MODULE					26.250
5.1.1	Economizer valve, atmospheric vaporizer & automatic cold cutting valve		22.000,00	1	22.000
5.1.2	Additional atmospheric vaporizer		4.250,00	1	4.250

5.2 REGULATION UNIT					25.000
5.2.1	Regulation unit		25.000,00	1	25.000
5.3 LOW PRESSURE ODORISER MODULE					450
5.3.1	Low pressure odoriser module (<20 bar) – 25 litres		2.375,00		
5.3.2	Low pressure odoriser module (<20 bar) – 50 litres		2.950,00		
5.3.3	Remote signals of low THT level		450,00	1	450
5.4 INTEGRAL MODULE COMPRESSOR - DISPENSER					156.000
5.4.1	Integ. module compressor-dispenser, 300 Nm^3/h, storage >500 l; 1 hose		135.000,00	1	135.000
5.4.2	Integ. mod. compressor-dispenser, 300 Nm^3/h, storage >500 l; 2 hoses		140.000,00		
5.4.3	Extra-cost of supplying RF-120 cabin		5.500,00	1	5.500
5.4.4	Extra-cost of supplying sound reduction cabin until 45 Db(A) at 10 m		8.500,00	1	8.500
5.4.5	Extra-cost of supplying blast-resistant cabin		7.000,00	1	7.000
5.5 CNG SYSTEM FOR FUTURE EXTENTIONS					163.550
5.5.1	PISTON PUMPS + ATMOSPHERIC VAPORIZERS				65.000
5.5.1.1	Cryogenic pistons pump for rates of 400 Nm^3/h Q= 11,6 l/m		40.000,00		
5.5.1.2	Atmospheric vaporizer of 400 Nm^3/h		14.000,00		
5.5.1.3	Cryogenic pistons pump for rates of 800 Nm^3/h Q= 20 l/m		50.000,00	1	50.000
5.5.1.4	Atmospheric vaporizer of 800 Nm^3/h		15.000,00	1	15.000
5.5.1.5	Cryogenic pistons pump for rates of 1.200 Nm^3/h Q= 34 l/m		60.000,00		
5.5.1.6	Atmospheric vaporizer of 1.200 Nm^3/h		16.000,00		
5.5.2	BOIL-OFF RECOVERY MODULE				90.000
5.5.2.1	Horizontal vessel		70.000,00	1	70.000
5.5.2.2	Reciprocating compressor		20.000,00	1	20.000
5.5.3	HIGH PRESSURE ODORISER MODULE				8.550
5.5.3.1	High pressure odoriser module(250 bar)		8.550,00	1	8.550

5.6 CNG STORAGE MODULE					22.700
5.6.1	External storage bottle rack, capacity 720 litres		8.000,00	1	8.000
5.6.2	External storage bottle rack, capacity 1.200 litres		14.000,00	1	14.000
5.6.3	Canopy for rack, capacity 720 litres		475,00		
5.6.4	Canopy for rack, capacity 720 litres		700,00	1	700
6. DISPENSERS					**83.643**
6.1 LNG DISPENSERS					83.643
6.1.1	Saturated LNG dispenser, 8 bar; -130°C; 2 supply points		35.000,00	2	70.000
6.1.2	Gas return flowmeter		3.500,00	1	3.500
6.1.3	Pocket nozzle heating		1.350,00	1	1.350
6.1.4	Automatic system for nozzle cleaning by compressor air		1.000,00	1	1.000
6.1.5	(INDOX) Return hose 1" with J.C. Carter connection		7.793,00	1	7.793
6.2 CNG DISPENSERS					28.000
6.2.1	CNG dispenser, 200 bar; 15° C; 1 supply point		23.000,00		
6.2.2	CNG dispenser, 200 bar; 15° C; 2 supply points		28.000,00	1	28.000
6.2.3	Additional cost for distance from containment > 25 m	m	100,00		
TOTAL - Technology D: super saturated and saturated LNG and CNG (L-CNG)					**771.283**

Taking into account the six available technologies, two stations of technology B, two of technology D, two of technology AM and one of technology DM have been built by Manufacturer M1. Therefore, reliable costs are only known in case of these technologies, not in case of A and C technologies. For B and D fix technologies, the proposed total cost is an average calculated from the real cost of both constructed stations in each technology. With the obtained deviation between the estimated costs and real costs an extrapolation has been applied on the estimated costs for A and C technologies in order to get a approximate real cost for each one.

All the above data are mostly coming from the experience of the LNG BC Partners having built the larger number of LNG refueling stations, (Manufacturer M1), both inside and outside the Project. For this reason these data are taken as main reference for this study. Other costs are available anyway also from the other Partners, (Manufacturer M2, M3 and M4), who built a smaller number of LNG refuelling stations. These additional costs, shown in a more condensed way, are reported below, for station type B, and type D.

Tab 3-6 Example of common and specific costs for technology B, saturated LNG and CNG (L-CNG) refuelling station (Manufacturer M2)

COMMON Costs	
1. SCOPE OF WORK AND SERVICES	
1.1 Engineering & procedures (Projects Authorization, Emergency plan, Licenses ans fees)	32.000
1.2 commissioning	48.000
2. ELECTRIC SYSTEM, CONTROL & TELECOMAND	
2.1 Electric system	78.000
2.2 Control system	20.000
2.3 TELECOMAND	
2.4 Payment system	
3. AUXILIARY FACILITIES	
3.1 Vents and drainages grids	11.000
3.2 Compressed air	
3.3 Firefighting facilities	
3.4 Property security	
3.5 Water for services	
TOTAL Common Costs	**189.000**
SPECIFIC Costs	
1. CIVIL	
1.1 CIVIL WORKS (Land purchase, Earthworks, Fencing, Containment, …) estimate	60.000
1.2 STRUCTURES (Canopies, lighting, control panels, defences, corporate image, …) estim	20.000
2. LNG STORAGE	
2.1 LNG vessel	140.000
2.2 Tank offloading system	10.000
3. LNG SYSTEM	
3.1 Centrifugal pump	68.000
3.2 LNG conditioners	48.000
4. CNG SYSTEM (boil-off recovery and/or L-CNG production)	
4.1 Boil-off recovering module	26.000
4.2 Regulation unit	8.000
4.3 Low pressure odorizer module & signals	0
4.4 Integral module compressor - dispenser	9.000
4.5 CNG system for l-cng delivery (hp pump+vaporizer; regulation system; piping & fittings)	90.000
4.6 CNG storage module	19.000
5. DISPENSERS	
5.1 LNG dispensers	75.000
5.2 CNG dispensers	16.000
Total specific Costs	**589.000**
TOTAL Costs	**778.000**

Tab 3-7 Example of common and specific costs for technology B, saturated LNG and CNG (L-CNG) refueling station (Manufacturer M3). This example applies to two refuelling stations that are very similar to each other (and same manufacturer); one of the two stations is among the first to be built, the other is among the last stations built.

COMMON Costs	
1. SCOPE OF WORK AND SERVICES	
1.1 Engineering & procedures (Projects Authorization, Emergency plan, Licenses and fees)	
1.2 commissioning	
2. ELECTRIC SYSTEM, CONTROL & TELECOMAND	
2.1 Electric system	
2.2 Control system	
2.3 TELECOMAND	
2.4 Payment system	
3. AUXILIARY FACILITIES	
3.1 Vents and drainages grids	
3.2 Compressed air	
3.3 Firefighting facilities	
3.4 Property security	
3.5 Water for services	
TOTAL Common Costs	**300.000**
SPECIFIC Costs	
1. CIVIL	
1.1 CIVIL WORKS (Land purchase, Earthworks, Fencing, Containment, …)	
1.2 STRUCTURES (Canopies, lighting, control panels, defences, corporate image, …)	
2. LNG STORAGE	
2.1 LNG vessel	
2.2 Tank offloading system	
3. LNG SYSTEM	
3.1 Centrifugal pump	
3.2 LNG conditioners	
4. CNG SYSTEM (boil-off recovery and/or L-CNG production)	
4.1 Boil-off recovering module	
4.2 Regulation unit	
4.3 Low pressure odorizer module & signals	
4.4 Integral module compressor - dispenser	
4.5 CNG system for l-cng delivery (hp pump+vaporizer; regulation system; piping & fittings)	
4.6 CNG storage module	
5. DISPENSERS	
5.1 LNG dispenser (one dispenser)	
5.2 CNG dispenser (one dispenser)	
Total specific Costs	**850.000**
TOTAL Costs	**1.150.000**

Table 3-8 Example of common and specific costs for technology B, saturated LNG and CNG (L-CNG) refueling station (Manufacturer M4)

COMMON Costs	
1. SCOPE OF WORK AND SERVICES	
1.1 Engineering & procedures (Projects Authorization, Emergency plan, Licenses, fees)	10.737,55 €
2. ELECTRIC SYSTEM, CONTROL & TELECOMAND	
2.1 Electric system	17.826,15 €
2.2 Control system	
2.3 Telecomand	
2.4 Payment system	28.000,00 €
3. AUXILIARY FACILITIES	
3.1 Vents and drainages grids	
3.2 Compressed air	
3.3 Firefighting facilities	1.650,00 €
3.4 Property security	4.500,00 €
3.5 Water for services	4.200,00 €
TOTAL Common Costs	**66.913,70 €**
SPECIFIC Costs	
1. CIVIL	
1.1 Civil works (Land purchase, Earthworks, Fencing, Containment, …)	69.665,42 €
1.2 Structures (Canopies, lighting, control panels, defences, corporate image, …)	15.303,00 €
2. LNG STORAGE	
2.1 LNG vessel	
2.2 Tank offloading system	
3. LNG SYSTEM	
3.1 Centrifugal pump	
3.2 LNG conditioners	
4. CNG SYSTEM (boil-off recovery and/or L-CNG production)	
4.1 Boil-off recovering module	9.750,00 €
4.2 Regulation unit	*418.500,00 €
4.3 Low pressure odorizer module & signals	
4.4 Integral module compressor - dispenser	
4.5 CNG system for l-cng delivery (hp pump+vaporizer; regulation system; piping & fittings)	
4.6 CNG storage module	
5. DISPENSERS	
5.1 LNG dispensers	
5.2 CNG dispensers	
TOTAL specific Costs	**513.218,42 €**
TOTAL Costs	**580.132,12 €**

**note: the total sum shown of 418.500,00 € also includes all four items of LNG system, from 2.1 to 3.2*

Table 3-9 Example of common and specific costs for technology D, super saturated LNG and CNG (L-CNG) refueling station (Manufacturer: still M1, but in a different country, and with larger storage tank)

COMMON Costs	
1. SCOPE OF WORK AND SERVICES	
1.1 ENGINEERING AND PROCEDURES (Projects Authorization, Emergency plan, Licenses ans fees) *	165.500,00 €
2. ELECTRIC SYSTEM, CONTROL & TELECOMAND	
2.1 ELECTRIC SYSTEM	54.000,00 €
2.2 CONTROL SYSTEM	
2.3 TELECOMAND	
2.4 PAYMENT SYSTEM	15.000,00 €
3. AUXILIARY FACILITIES	
3.1 VENTS AND DRAINAGES GRIDS	5.000,00 €
3.2 COMPRESSED AIR	4.000,00 €
3.3 FIREFIGHTING FACILITIES	26.500,00 €
3.4 PROPERTY SECURITY	12.000,00 €
3.5 WATER FOR SERVICES	4.000,00 €
TOTAL Common Costs	**286.000,00 €**
1. CIVIL	
1.1 CIVIL WORKS (Land purchase, Earthworks, Fencing, Containment, …)	126.300,00 €
1.2 STRUCTURES (Canopies, lighting, control panels, defences, corporate image, …)	58.500,00 €
2. LNG STORAGE	
2.1 LNG VESSEL (100 m^3)	170.000,00 €
2.2 TANK OFFLOADING SYSTEM	9.200,00 €
3. LNG SYSTEM	
3.1 CENTRIFUGAL PUMP	0,00 €
3.2 LNG CONDITIONERS	36.000,00 €
4. CNG SYSTEM (boil-off recovery and/or L-CNG production)	
4.1 BOIL-OFF RECOVERING MODULE **	35.500,00 €
4.2 REGULATION UNIT	160.700,00 €
4.3 LOW PRESSURE ODORIZER MODULE & SIGNALS	
4.4 INTEGRAL MODULE COMPRESSOR - DISPENSER	
4.5 CNG SYSTEM FOR L-CNG DELIVERY (hp pump+vaporizer; regulation system; piping & fittings)	
4.6 CNG STORAGE MODULE	
5. DISPENSERS	
5.1 LNG DISPENSERS	72.000,00 €
5.2 CNG DISPENSERS	16.500,00 €
TOTAL Specific Costs	**684.700,00 €**
TOTAL Costs	**970.700,00 €**

notes

** Of which: Authorization = 98.500 €; Engineering = 67.000 €*

*** compressor + tank for recovery of vapor from truck tanks*

Table 3-10 Example of common and specific costs for technology D, super saturated LNG and CNG (L-CNG) refueling station

COMMON Costs	
1. SCOPE OF WORK AND SERVICES	
1.1 ENGINEERING AND PROCEDURES (Projects Authorization, Emergency plan, Licenses ans fees)	50.000,00 €
2. ELECTRIC SYSTEM, CONTROL & TELECOMAND	
2.1 ELECTRIC SYSTEM	30.000,00 €
2.2 CONTROL SYSTEM	55.000,00 €
2.3 TELECOMAND	0,00 €
2.4 PAYMENT SYSTEM	0,00 €
3. AUXILIARY FACILITIES	
3.1 VENTS AND DRAINAGES GRIDS	0,00 €
3.2 COMPRESSED AIR (included in 2.2)	0,00 €
3.3 FIREFIGHTING FACILITIES	1.500,00 €
3.4 PROPERTY SECURITY	0,00 €
3.5 WATER FOR SERVICES	0,00 €
TOTAL Common Costs	**136.500 €**
SPECIFIC Costs	
1. CIVIL	
1.1 CIVIL WORKS (Land purchase, Earthworks, Fencing, Containment, …)	90.000,00 €
1.2 STRUCTURES (Canopies, lighting, control panels, defences, corporate image, …)	35.000,00 €
2. LNG STORAGE	
2.1 LNG VESSEL	150.000,00 €
2.2 TANK OFFLOADING SYSTEM	86.000,00 €
3. LNG SYSTEM	
3.1 CENTRIFUGAL PUMP	45.000,00 €
3.2 LNG CONDITIONERS (included in 3.1)	0,00 €
4. CNG SYSTEM (boil-off recovery and/or L-CNG production)	
4.1 BOIL-OFF RECOVERING MODULE	45.000,00 €
4.2 REGULATION UNIT (included in 4.1)	0,00 €
4.3 LOW PRESSURE ODORIZER MODULE & SIGNALS (included in 4.4)	0,00 €
4.4 INTEGRAL MODULE COMPRESSOR - DISPENSER	140.000,00 €
4.5 CNG SYSTEM FOR L-CNG DELIVERY (hp pump+vaporizer; regulation system; piping & fittings)	120.000,00 €
4.6 CNG STORAGE MODULE (included in 4.4)	0,00 €
5. DISPENSERS	
5.1 LNG DISPENSERS (included in 4.5)	0,00 €
5.2 CNG DISPENSERS (included in 4.4)	0,00 €
TOTAL Specific Costs	**711.000 €**
TOTAL Costs	**847.500 €**

In the next table the fixed and variable estimate and actual costs are summarized for the different technologies, calculated from the above tables and other sources.

There are differences between the stations final price and the theoretical estimated costs listed before. As prices of equipment, facilities and assemblies are known prior to the project implementation, deviations in all cases occur for example in the phase of civil works. The justification is that the cost of civil works cannot be predicted accurately, as each location is different and ground features of each site with own difficulties, giving completely different budgets for each project.

Tab 3-11 Summary of estimated and actual costs for the different technologies of stationary refueling stations

technologies	A	B	C	D
	saturated LNG at 7-8 bar	**saturated LNG and CNG (L-CNG)**	**super saturated (18 bar) and saturated LNG**	**super saturated and saturated LNG and CNG (L-CNG)**
Common costs estimate.	170.640			
Specific costs estimate	283.818	681.283	373.818	771.283
Total cost estimate	**454.458**	**851.923**	**544.458**	**941.923**
Common cost actual		**67.000**		
Total cost actual	**470.318**	**580.000** ÷ **814.293**	**563.459**	**970.700** ÷ **1.150.000**

In general, from a review on a wider scope, it can be stated that the total cost of public LNG+L-CNG refuelling stations varies in the range: **580.000÷1.150.000** €, but it can in some case also peak up to 1.800.000 €.

Some estimation has been done on the cost of mobile refuelling stations, based on real cases.

Tab 3.12 Estimated costs of mobile stations

technologies	A	D
	saturated LNG at 7-8 bar	**super saturated and saturated LNG**

		and CNG (L/CNG)
Cost actual	**301.000**	**473.000**

As comparison, we report the result of calculation of costs done by the Oxford Institute for Energy Studies (CAPEX and OPEX) for CNG, LNG, and L-CNG refuelling stations for different size (delivery rate).

Indicative costs of CNG filling stations (Source: Oxford Institute for Energy Studies)

	CNG station		*LNG station*		*L-CNG station*	
Size (kg/d)	CAPEX ('000 €)	OPEX (€/MWh)	CAPEX ('000 €)	OPEX (€/MWh)	CAPEX ('000 €)	OPEX (€/MWh)
500	200	21	90	13.1	190	21
1,000	250	12.3	120	7.9	250	12.3
5,000	440	7.1	330	2.7	630	10.4
10,000	880	6	440	2.7	1000	7.9

Fig 3-1 CAPEX and OPEX of CNG, L-CNG and LNG refueling stations (Oxford Institute for Energy Studies)

3.5 Specific features of the different technologies

There is no one solution better than the other, but each one is optimal in a given scenario composed of several factors to be taken into account before deciding which technology is the most appropriate:

- Expected fuel consumption
- Predominance of consumption of LNG, CNG or both
- Types of vehicles which potentially will refuel in the station
- Clearances site
- Operating costs
- Investment capacity and payback expected period

In general, as already outlined earlier in the document, if there is CNG demand, it inevitably involves choosing one technology B or D. If the future scenario of the station contemplates a substantial LNG consumption compared to a moderate CNG consumption, the best option might be to B, since the boil-off own generation could supply the CNG demand without the need of producing it with high pressure pump and evaporator.

The technology B can only supply LNG to 8 bar, which limits the market for the type of vehicles which are just able to refuel saturated LNG. However, the trend of LNG vehicle manufacturers is to unify their technology to saturation conditions at 8 bar, so that this variable should not be a problem in the future.

The LNG predicted consumption should be determinant. As it is abundant, technology B may not be sufficient to meet demand as it is limited by a single supplier (1 hose) because of the principle of LNG transferring by pressure difference between the LNG vessel and the tank of vehicle. The technology D supplies by submerged cryogenic pump (typical power: 16 kW), so no such restriction exists.

In addition, if a high CNG consumption is also expected, it should be taken into account the energy consumption of the station. In this scenario the optimal technology is D, as for CNG production uses a cryogenic reciprocating pump that compresses LNG before being vaporized, contrary to the compressor required in the case of B technology in order to compress the gas after being vaporized, since there is no pump. Energy consumption is far lower for pump than the compressor (fig 4). Therefore, the energy cost is substantially lower in the case of D technology. The optimal working conditions of this typical reciprocating pump of D technology occur when CNG production is practically constant. Thereby as the pump has no chance to get heated during stand-by periods, no pre-cooling is needed, and the consequent generation of boil-off decreases. As the LNG is flowing regularly to be vaporized due to the constant demand, the pump is kept cool, so there is no need of recirculation cycles to pre-cool it. Thus is, no pre-cooling, less heat took out from the pump via lng, so less heat carried inside the LNG tank.

The goals to achieve with the future LNG stations should be:

- Being able to supply LNG and CNG
- LNG supplied mostly at saturation conditions (8 bar)
- Ideally high consumption of both CNG and LNG
- Low generation of boil-off, as consequence of the previous one
- Minimizing energy consumption of the station

In order to comply with previous goals, the optimal option is to implement D technology (without the LNG conditioner control system "on fly" which supplies at supersaturated LNG conditions, if only saturated LNG is necessary) always if there is investment availability and the payback period allow it.

3.6 Further development of the LNG infrastructure in Europe

To calculate the total cost of infrastructures for a second step development of the infrastructure, it has been taken as baseline a need to build additional 29 stations, as result of a separate study done by some Partners of the Project. A detailed study of the location and customers of the different proposed stations will be necessary to decide which type of technology to install in each location. Nevertheless this detailed study is out of the scope of this project. Therefore it is assumed that all the installed stations will be built with technology D (the best option if there is budget enough), and 70% of them (20 stations) will be fixed stations and the remaining 30% (9 stations) will be mobile stations.

The following table shows the total cost of proposed infrastructure in Europe under the above conditions.

Tab 3.13 Total infrastructure cost for the second step deployment of an European plan

	Stationary (normal) station	Mobile station	Total cost
Infrastructure cost €	**20.985.000**	**4.257.000**	**25.242.000**

4 Operational costs of LNG and L-CNG stations

Due to the limited number of LNG refuelling stations active in Europe, most of which are quite new, no extensive data is available yet on this item. Operational costs are dependent on location, age, size and type of the station. All the stations in operation in Europe are almost brand new. The main operational costs are fixed, e.g. CAPEX depreciation, personnel (except in some cases), maintenance to a certain extent, management and administration. Some costs are instead proportional to the sale of LNG and L-CNG, such as boil-off compression, LNG pumping, L-CNG pumping, electricity consumption for general purposes (light, heating, services pumps, air compressor). The cost for personnel may become also proportional to gas sale in some cases. For example in the case of CODO stations (CODO = Company Owned, Dealer Operated). Examples of operational costs are offered in the next table. Some operational costs may not be easy to define at this stage. For example, in the case of the maintenance cost, as the operators may stipulate contracts with the refuelling station suppliers which include this item for the first 2 years of operation.

The operational costs are based on actual figures and also on assumptions, e.g.:

- The reference station assumed is type D, as it is considered to be the most suitable to the development of the market.
- For CAPEX the total figure has been considered. The amount subsidized through the Project was not subtracted from CAPEX, so that the real costs of any station are calculated. The highest figure (hence worst case) has been assumed at: **1.150.000 €**
- The depreciation of CAPEX is based on a period of 10 years; 10 year is a reasonable (minimal) length of time in which no substantial repair or extraordinary maintenance work is needed, that might lead to an increase of CAPEX. This is anyway a conservative approach to depreciation time, as in the real world, a period of 18 to 20 year would be more realistic, thus leading to a better profitability analysis, with a lower annual depreciation cost. Of course this does not take in consideration the option (generally preferable) of a modular development process of the station, in which the initial CAPEX is minimized, then followed by further investments for additional modules to follow the market trend. In this evaluation the investment is assumed to be done entirely at the beginning of the process. Generally, a modular process would anyway improve the profitability of the initiative. With the modern technology, modules can easily be added and subtracted.
- The depreciation rate is 5%. Also this approach is conservative. A rate of 5% can be considered a bit high, given the present general economic situation in Europe. This situation is hoped not to last in time anyway.
- For the management and administration cost of filling stations, an average figure has been assumed at: **20.000 €/y**. Some partners report on financial cost as 2.000 €/month.
- Personnel; in case of attended multi-fuel refuelling station, an estimate of one person in addition to the staff already working in the original gasoline/diesel station is considered sufficient; the cost varies country by country. An average cost has been considered at 17.000 €/year for one person. In the case of mono-fuel refuelling station, it is either self-service 24H, which needs no personnel, or it is attended, in which case at least two/three persons are needed. As a compromise, the case of two persons has been chosen as example in the analysis, at a cost of **35.000 €/year**. In the case of CODO, the Gas or energy company owner of the station may reward the dealer with a sum, proportional to the gas sale. This sum may be assumed to be e.g. 4-5 Euro-cent per kg of LNG or L-CNG sold.

- The calculation of the electric energy required for L-CNG production is quite easy and definite. It is also easy to make an appraisal of the energy requirement for the low-pressure LNG transfer pump if present. It is less easy instead to do a right estimate of all the other energy applications in the station, i.e. illumination, ancillaries (e.g. air compressors for receptacle and connector cleaning, water pumps, control panels etc.). some partner report on a cost as 2.000 €/month for a sale rate of 63.000 kg/month, hence: 0,032 €/kg. Ffor the cost of power, an average figure has been adopted. Price of electricity (industrial) in Euro area = **0,128 €/kWh**
- For the sale rate, the case of the refuelling station RS1 has been taken as reference. In this station the trend has been constantly increasing, eventually stabilizing at an average 88.00088 t kg/month over the last 10 months operation. The average delivery rate of that period has been adopted, hence with a corresponding annual sale of **1.056 .000** tkg/year. This is at present the best case in the Project. The market will anyway very likely settle far higher than that before the end of the duration period of the Project, in this station and hopefully in many or all the other stations as well.
- Natural gas supplied to the station; it is a gas production + transport cost, or a gas purchase cost, depending on the configuration of the station owner/operator, whether it is a gas Company or a station dealer. The gas purchase cost has been considered at 0,2÷0,25 €/Nm^3; (0,29-÷0,36 €/kg). The lowest figure has been used at 0,2 €/Nm^3; **0,29 €/kg**. some partner reports anyway a cost of Natural gas at 0,206 €/kg.
- Maintenance costs have shown so far to be variable on a quite wide range for the considered refueling stations. The main maintenance costs were reported for a period of 12 to 21 operation months, from 5 of the BC stations. As in other cases when costs are involved, the survey is done in a way as to not disclose any connection between figures and sources. Also in this case, the stations are assigned a random name (RS I, RS II, ……VI), which is not in connection to the same names used elsewhere in the document, for a different or similar group of stations. The stations have different length of reporting periods, ranging from 12 to 21 months. So the costs have been recalculated on the 12 months basis, for integrity of comparison, and also for the reason above. The costs include: Configuration changes, Repairs, Scheduled maintenance. If only considering the scheduled maintenance cost, a figure of **1%** of CAPEX can be assumed to be representative in general.

Tab 4-1 Reported maintenance costs for 5 stations

Filling station	**Total maintenance cost calculated on 12 months** **€**	**Share of maximum considered CAPEX (1.150.000 €)** **%**	**Scheduled maintenance cost calculated on 12 months** **€**	**Share of maximum considered CAPEX (1.150.000 €)** **%**	**Total hours of technical assistance required from manufacturer of filling station**
RS I	6.960,00	0,6	6.428,00	0,6	12
RS II	61.570,00	5,3	42.130,00	3,7	430
RS III	3.175,00	0,3	3.175,00	0,3	119
RS IV	n.a.	n.a.	n.a.	n.a.	3

RS V	67.370,00	5,8	18.930,00	1,6	50

Tab 4-2 Estimate of operational costs of an LNG + L-CNG refuelling station

Assumptions: **CAPEX = 1.150.000€; sale = 1.056.000 kg/y; 1 person**	**Figure €/year**	**Specific figure €c/kg**
Costs independent from sale rate (at least to a certain extent)		
Depreciation of CAPEX (10 y; 5%) →E= 0,129507 x CAPEX	149.000	14,1
Personnel ~~(1 person)~~ (2 persons)	35.000	3,3
Management & Administration (1 manager part time + 1 financial assistant part time)	20.000	1,9
Maintenance (1% of Capex)	10.000	0,9
Technical cost (certify, testing etc.)	10.000	0,9
General (phone, cleaning, illumination etc.)	4.000	0,4
Sub-total independent costs	**228.000**	**21,5**
Costs proportional to sale rate		
Natural gas purchase (0,2 €/Nm^3; 0,29 €/kg)	306.000	29
L-CNG high pressure pumping (L-CNG) (0,03 kWh/kg x 12,8 €c/kWh)	4.000	0,4
LNG pumping (LNG) (0,01 kWh/kg x 12,8 €c/kWh)	1.500	0,1
Boil-off compression; air compressor etc.: not predictable		
Sub-total proportional costs	**311.500**	**29,5**
Total	**539.500**	**51**

Actual low profile cases

The case of one of the stations, which is at present in a very early stage of operation, has been reported. The station is initially delivering only 40 ton per month of LNG (480 ton/year). For the items:

- Salaries and SG&A,
- Maintenance spare parts,
- Financial costs and station depreciation,
- Electricity consumed by, and natural gas supply to station,

A total OPEX was reported as 36.000 €/month, i.e. 432.000 €/year; hence a specific OPEX of: **90,00 €c/kg**

As the Project is still in infancy, these total operational costs are likely to drift over the time, generally in a favorable direction. Part of OPEX, i.e. salaries, financial overall costs, administration and management, maintenance etc. tend to be fixed, irrespective of the delivery rate; at least to the extent to which an increase of sale do not require more persons at the pump. Some other costs will increase, close following the trend of the delivery rate. Due to this, in general some specific costs (in terms of €/kg) such as personnel and depreciation will go down with an increasing delivery rate; thus improving proportionally the profitability. The proportional specific costs will tend to keep at the same level, so not affecting the overall profitability of the station. But they may also slightly decrease as consequence of better efficiency, or possible improvement of NG purchase contract, at delivery rates closer to regime (design figures).

Another case of a station which is at beginning operation has also been reported. This case is definitely not indicating a reference situation, and it is very far from average conditions. This is a temporary station, rented, during the construction of the proper one.

The OPEX of this station, excluding rental of course, and excluding depreciation, is reported at 10.000 € per month, including:

- maintenance
- spare parts
- salaries
- electricity and gas.

The LNG delivery rate of the station is 10 t per month

So the specific OPEX, not including depreciation cost, in this case is: 1 €/kg, i.e. 0,7 €/Nm^3

These OPEX are especially high because at the time of preparation of this report, this station is at the very beginning of operations and the level of consumption doesn't allow yet to optimize the LNG purchase and mostly LNG transport.

5 Analysis of profitability of LNG and L-CNG refuelling stations

An analysis of profitability, in terms of gross yearly income (before tax) has been done, based on the following main conditions:

Excise duty: The current national tax situations in Europe must be taken in consideration, as it is not homogeneous. At present, and hopefully so also in the future, 18 Member States do not have excise duty on NG used as a fuel, or tax it anyway below the current min. level of 2,6 €/GJ. For the analysis, as worst case, this figure will be used of **2,6 €/GJ**.

The net heating value of NG is: 33-38 MJ/Nm^3 For NG (Directive 2009/33 EC Annex - Table 1: Energy content of motor fuels); the average value is: 35,5 MJ/Nm^3.

With a density of NG of 0,7 kg/Nm^3, it becomes: 50 MJ/kg, which apply also to LNG.

The equivalent excise duty is in this case: (2,6 / 1.000) x 50 = **13,00 €c/kg**.

VAT: an average figure of **20%**, also applied to excise duty, has been considered.

OPEX: the average figures shown in *Tab 4-2* have been used.

As for the actual and predictable LNG and L-CNG sales rate: the different situations are considered as follows:

- 40.000 kg/Month 480.000 kg/y
- 60.000 kg/month 720.000 kg/y
- 80.000 kg/month 960.000 kg/y
- 100.000 kg/month 1.200.000 kg/y
- 120.000 kg/month 1.440.000 kg/y
- 140.000 kg/month 1.680.000 kg/y

The pump price options examined are:

- 0,8 €/kg
- 0,9 €/kg
- 1,0 €/kg
- 1,1 €/kg
- 1,2 €/kg

The cost of gas supply has been considered as: **0,29** €/kg (range: 0,29÷0,36 €/kg; i.e. 0,20÷0,25 €/Nm^3; 0,02÷0,025 €/kWh).

Some partners of the Project report anyway a cost of NG at 0,206 €/kg.

The graphs in *Fig 5-1* and *Fig 5-2* show the trend of pay-back time of a station with CAPEX 1.150.000 € and 850.000 € respectively, in the case of different sale prices, considering an excise duty of 13 €c/kg to be applied on the LNG sold. Shorter pay-back times can be attained in case of partial or total excise exemption, as is the case in most European Countries. Encouraging results are shown for a gas sale rate above 80 ton/month in the case of price at pump higher than 1,0 €/kg.

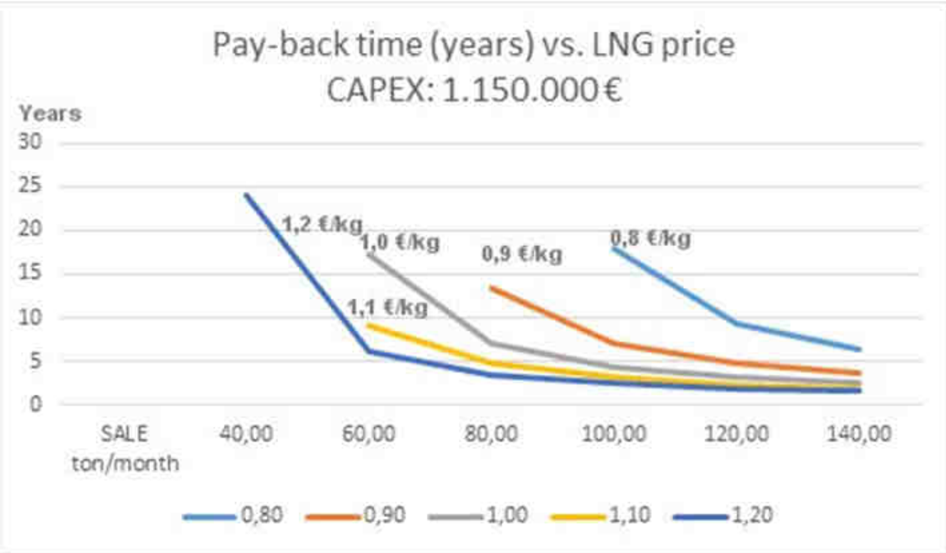


Fig 5-1 pay-back time with different sale rate and price of LNG at pump (CAPEX: 1.150.000 €)

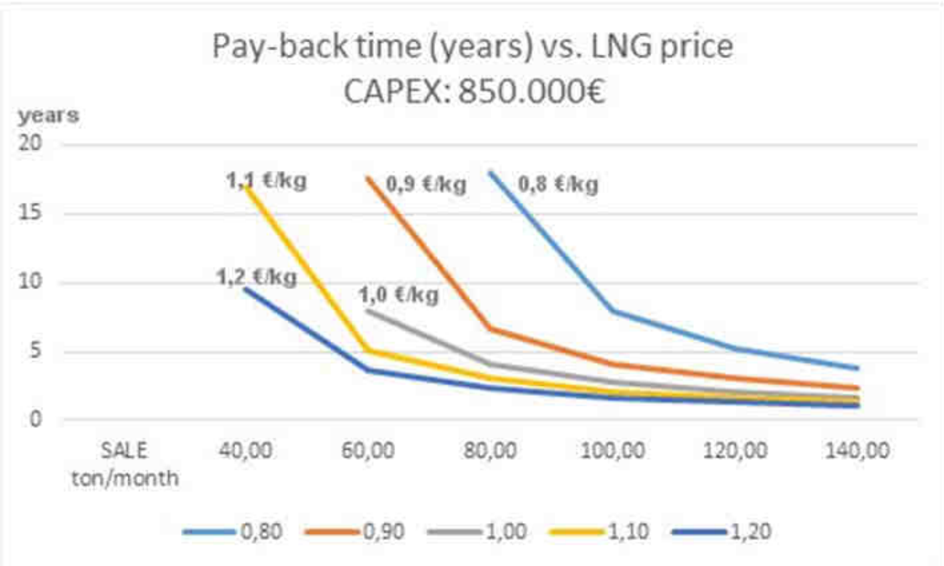


Fig 5-2 pay-back time with different sale rate and price of LNG at pump (CAPEX: 850.000 €)

The graphs in *Fig 5-3* and *Fig 5-4* show the trend of the gross yearly income before tax that can be expected, also in this case for a station with CAPEX 1.150.000 € and 850.000 € respectively, and with different sale prices, considering an excise duty of 13 €c/kg. A higher yearly income can be obtained of course in case of partial or total excise exemption.

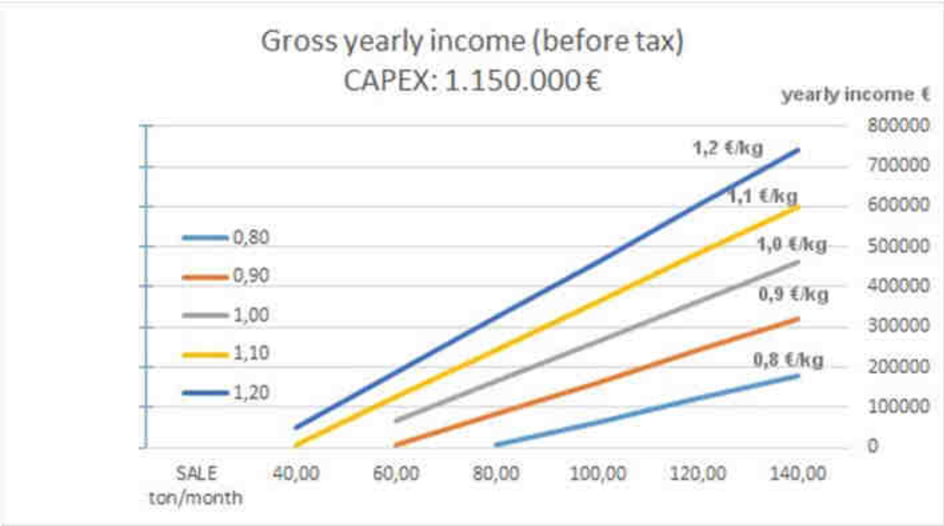


Fig 5-3 Gross yearly income (before tax) with different sale rate and LNG price at pump (CAPEX: 1.150.000 €)

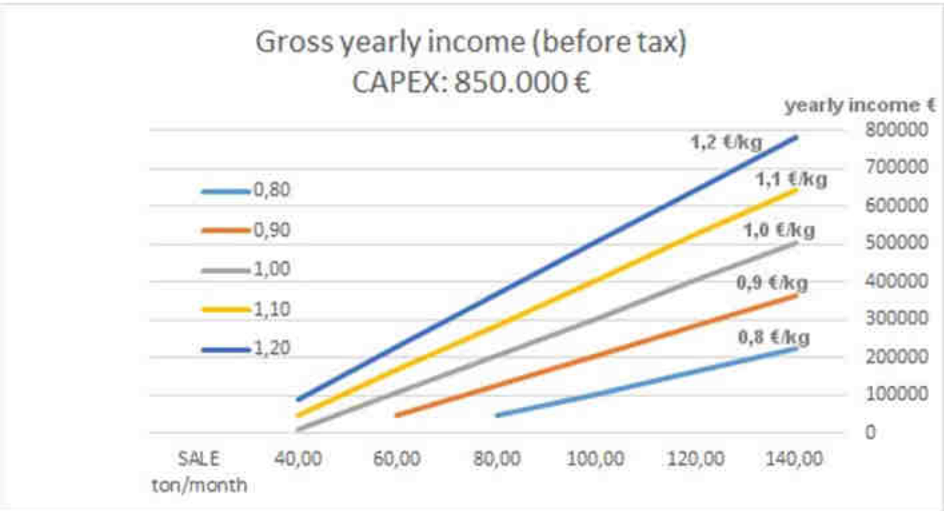


Fig 5-4 Gross yearly income (before tax) with different sale rate and LNG price at pump (CAPEX: 850.000 €)

6 Panoramic of LNG price in Europe

The operators of LNG stations in some countries have chosen to apply to LNG more or less the same price at pump (per KG) which they apply for CNG. Where this is the case, it is mainly due to marketing and promotional reasons, as producing LNG or get the supply, is generally more expensive compared to CNG, and all the industrial risk of a new products is on the field. Furthermore, for the LNG customers this fuel necessarily includes an additional value, which they should be ready to pay for, and which the operators will want to monetarize in future, when the LNG market will have been grown up to a more satisfactory (less pioneering) level.

But even when this market is settled in future, the price at pump of LNG must set anyway over time at an appropriate level, to meet an acceptable compromise between some basic requirements and conditions, e.g.:

- The price at pump of LNG must be sufficiently below that of diesel oil, to allow truck drivers/owners a saving in operational cost of the vehicle; this is a necessary condition to economically justify the choice of LNG as fuel. For example, probably a net saving which is lower that 20% would hardly encourage the truck drivers/owners to go for LNG, and to spend 15-20% more for the vehicle's purchase, compared to the diesel equivalent version. Especially nowadays, in a period when they well know that the trip itineraries are to be planned carefully beforehand, to match the running range of trucks with the scarce dissemination of LNG refuelling stations on the territory.
- The difference in price at pump between LNG and diesel must also take in account that the apparent economic advantage of LNG, as suggested by comparison of the prices per litre diesel equivalent, is reduced as a matter of fact, by effect of the higher thermodynamic efficiency of the diesel engine, which takes more profit of the energy content of the fuel. An efficiency higher by some 10-15% can be expected from the HD diesel engines today, compared to the HD Otto engines running on natural gas, be it compressed or liquefied. Even HD engines dedicated and optimized for natural gas cannot fill this gap completely yet. This difference will substantially decrease in future anyway, and eventually disappear, thanks to innovative technologies, such as e.g. HPDI, high pressure direct injection. Also modern dual fuel technology offers a benefit on this respect, given that in this case natural gas is used in a cycle which is very close to the diesel cycle.
- The availability of LNG in the LNG refuelling station offers the side advantage of selling also L-CNG, with substantial savings on the compression side (up to 90% saving, because pumping a liquid instead of compressing a gas to 200 bar is cheaper). Some part of this saving can be taken in account when determining the price at pump of LNG.
- The L-CNG has some advantages compared to the normal CNG obtained by compression, e.g.: potentially stable composition and higher net heating power; lower gas temperature, allowing better filling rate of the vehicle tank. All this results in longer running range on CNG for the vehicle driver (due to heating power and gas temperature), and higher sale rate for the station operator (due to gas temperature). This also means that L-CNG can be sold at a slightly higher price, thus curbing the need to rise the LNG price at pump.

LNG and CNG price vs Diesel

Country	LNG price		CNG price		VAT	Excise duty	Diesel price
	€/kg	**€/l e Diesel (1)**	€/kg	€/l e Diesel (1)	[%]	€/kg	€/l
Italy	0,98	**0,71**	0,98	0,71	22	0.0047	**1,52**
Belgium	0,98	**0,71**	0,98	0,71	21	n.a.	**1,29**
Spain	1,00	**0,72**	1,05	0,76	21	n.a.	**1,18**
France	1,05	**0,76**	1,05	0,76	20	0,057	**1,13**
Germany	n.a.	**n.a.**	1,09	0,78	19	0,196	**1,22**
UK	1,20	**0,86**	1,25	0,90	20	n.a.	**1,65**
Netherlands	1,22	**0,88**	0,93	0,67	21	0,23	**1,36**
Portugal	1,23	**0,89**	0,58	0,42	23	n.a.	**1,29**
Sweden	1,67	**1,20**	1,83	1,32	25	0,351	**1,38**
(1): prices in litre equivalent of diesel; based on the net heating values: LNG = 50 MJ/kg; diesel = 36 MJ/litre (Directive 2009/33/EC); reference is made to energy input to the engine.							

Fig 6-1 LNG and CNG pump price in Europe

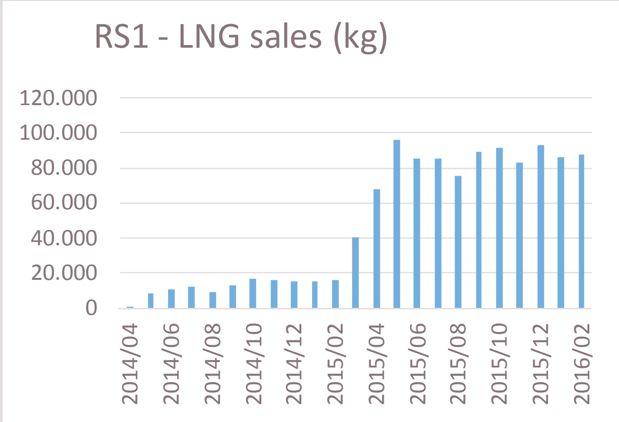
7 LNG sale rate of stations

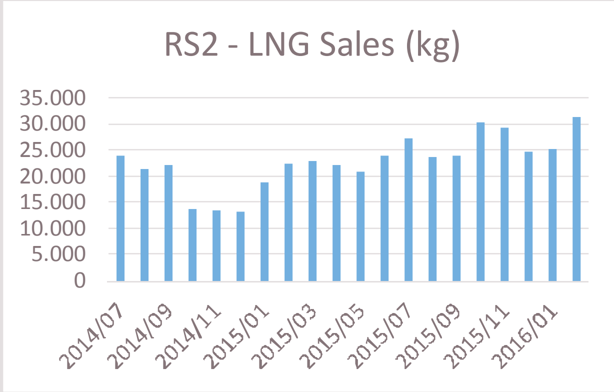
The sale rate of some of the stations is reported as examples of good and weak progress (*Fig 7-1*), based on data available as of September 2016. The most settled 6 stations, out of the 13 in operation, were selected for this analysis; also because more data is already available for them. The case of RS1 is the best performing, having reached a total sale of ~1.119 ton, i.e. 58% of the total of the reported stations (~1.975 ton), a very robust figure. The station was among the first to be inaugurated in the Project. By the end of the Project it is hoped that the diagrams will reach more successful levels also for the other stations, as the present trend already show in most of the cases, even if not all of them.

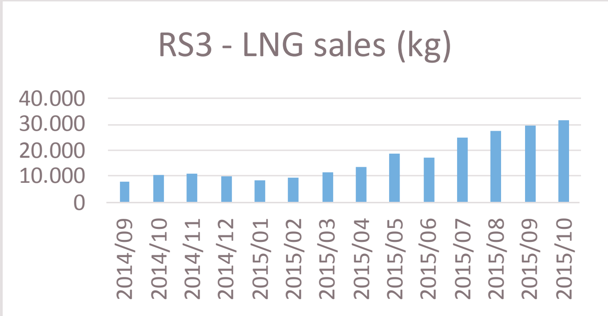
The worst case at present is RS4. It is the second last in terms of total sale, but as a matter of sales trend diagram, it is sure the less performing one, notwithstanding that it was also among the first stations to be inaugurated. The diagram of RS5, even if low profile, shows anyway a globally increasing trend. The diagram of RS4 is instead fluctuating at a constantly low level. The reason for this may be that LNG there is sold at a price which is maybe too high to be appalling for customers. The station RS5 anyway is also selling at low level compared to the others, despite offering a far lower price of LNG. A partial explanation of this is, maybe, that RS5 started operation quite late in comparison to the examined group of stations. The station RS3 is also offering a quite high price of LNG, but its sale rate looks encouraging enough, and the trend diagram shows a constant increase, month after month. In this pictures also the option of L-CNG offers an help to the total sale trend.

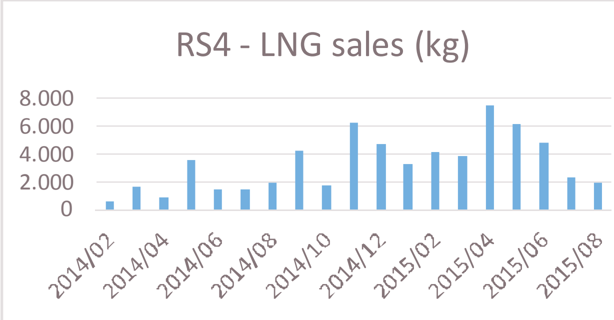
Tab 7-1 Station statistics

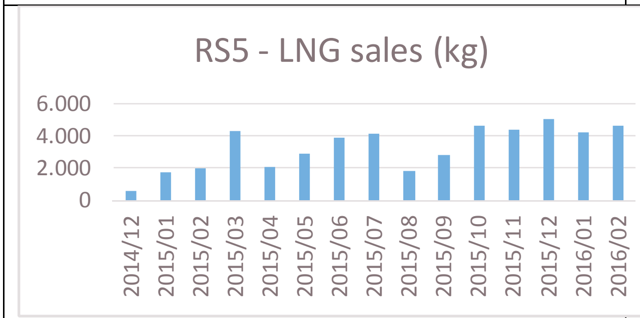
Refuelling station	Total sale in the period from opening to early 2016 (kg)	Total number of filling operations	Average price of LNG (€/kg)	Average amount of LNG sold per filling operation (kg)
RS1	**1.119.372**	**10.539**	0,969	106
RS2	457.265	3.248	0,988	141
RS3	235.554	1.965	1,221	120
RS4	63.489	529	**1,606**	120
RS5	**49.794**	**421**	**0,892**	118
Grand total	**1.925.474**	**16.702**		**115**











RS6 (graph not available)

LNG + CNG sales= 63.000 kg/month

Fig 7-1 sale rate diagram of five selected stations

8 Conclusions

The LNG technology is more than mature also in Europe, as it is in other parts of the world e.g. Asia and North America. In Europe it is anyway still far from being commercially mature. There are now still less than 100 LNG stations in operation or under construction in Europe. The main consequence of this is that the costs of LNG refuelling stations in Europe still suffer from a strong lack of scale effect. Many important and expensive components are still sold on a case by case basis. This tends to impair competition between manufacturers, and viability to install powerful assembly lines. Further development of this market will certainly provide a decrease of average prices of the main components. In the direction of better economy will go also the imminent publication of European norms (CEN) for LNG and for CNG refuelling stations, in parallel to what is happening to equivalent International (ISO 16924) norms. This will very likely provide harmonization, hence some benefit also on the economical side of this sector.

The cost of any project could strongly vary with the adopted technology, and also depending on the location, state and conditions of the chosen installation site. For this reason, it should be noted that the resulting table of costs shown in this document must be intended as indicative costs of standard projects. In the assessed technologies for stationary stations it is worth making a distinction between fixed cost items (or very similar costs between all of them), and variable cost items depending on the own technology used and on the selected site. The budget for civil works strongly varies depending on the final location of the station, therefore it should not be taken into account when extrapolations of cost are developed from one station to other.

At the beginning of the LNG infrastructure development process, while the LNG consumption is low, it is crucial that the technologies implemented avoid the emission of boil-off. If the station supplies both LNG and CNG the generated boil off is not released to the atmosphere but it is sold as CNG. Moreover D technology i.e. super saturated and saturated LNG and CNG (L/CNG) minimizes the energy consumption of the station because uses pump instead of compressor. Therefore it is believed that the optimal technology is D, if the capacity of investment and payback period allow it. Some improvements for D technology are being assessed. The main goal is to optimize the facilities and to simplify the operation of the stations. With these improvements also investment and operating costs could be reduced.

For the calculation of the total infrastructures cost for future planned stations, it has been assumed that 70% of them will be fixed and 30% remaining will be mobile. It results in 20 fixed stations and 9 mobile stations. The calculation of total infrastructure cost results above 25.000.000 €.

Mobile and movable stations are a good tool for the pioneering period of building up an LNG infrastructure. They are available at reasonable cost, are quite flexible and can be relocated: if not successful, to a better destination, or when successful enough to be replaced with permanent structures, having a larger delivery capacity. The main part of operational costs (OPEX) are independent from the amount of gas sold, at least to a certain extent. This is a big challenge in the start-up period, but is improving the balance of the initiatives as the sale rate increases.

The analysis done is based on the whole CAPEX, without taking into account any financial incentives, and assuming a taxation (excise duty) at the harmonised level in Europe. It shows interesting results only for sale rate above a certain limit, i.e. 80 ton per month, and for price of LNG at the pump higher than 1 €/kg. A partial or total exemption from excise duty, in the Countries where this apply, can improve the business of stations in any case.

9 Appendix

9.1 LNG trade price

Fig 9-1.1 Estimate of LNG prices worldwide

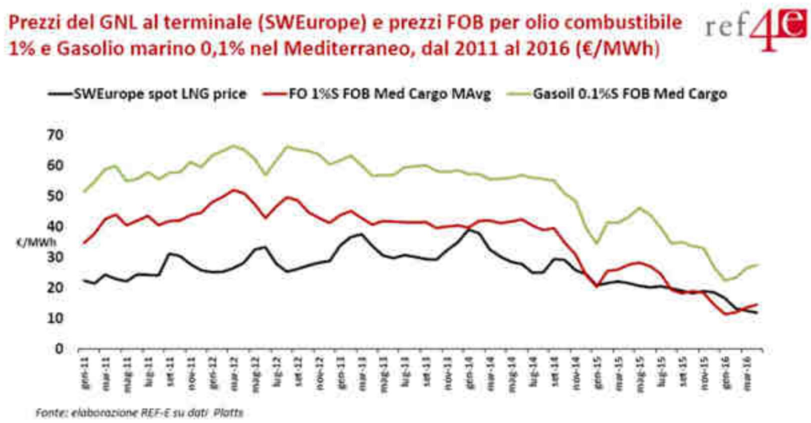


Fig 9-1.2 Trend of prices of LNG in Europe

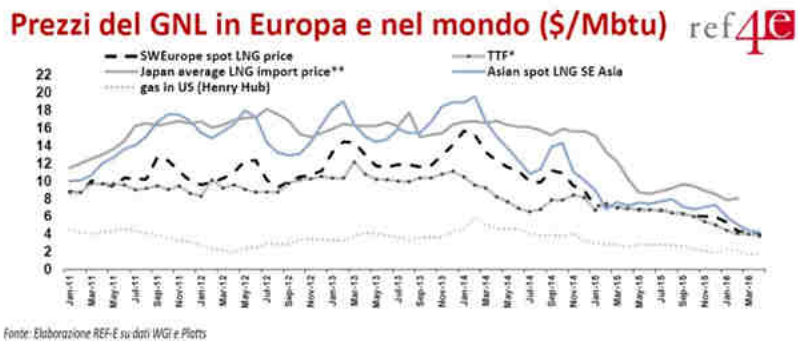


Fig 9-1.3 Trend of prices of LNG in Europe and worldwide

9.2 Composition of LNG worldwide

LNG CHARACTERISTICS (2012 UPDATE)

The average composition is chosen as being representative among compositions reported by the different receiving terminals.

Origin	Nitrogen N2 %	Methane C1 %	Ethane C2 %	Propane C3 %	C4+ %	TOTAL	LNG Density [1] kg/m³	Gas Density [1] kg/m³(n)	Expansion ratio m³(n)/ m³ liq	Gas GCV [1] MJ/m³(n)	Wobbe Index [2] MJ/m³(n)
Australia - NWS	0.04	87.33	8.33	3.33	0.97	100	467.35	0.83	562.46	45.32	56.53
Australia - Darwin	0.10	87.64	9.97	1.96	0.33	100	461.05	0.81	567.73	44.39	56.01
Algeria - Skikda	0.63	91.40	7.35	0.57	0.05	100	446.65	0.78	575.95	42.30	54.62
Algeria - Bethioua	0.64	89.55	8.20	1.30	0.31	100	454.50	0.80	571.70	43.22	55.12
Algeria - Arzew	0.71	88.93	8.42	1.59	0.37	100	457.10	0.80	570.37	43.48	55.23
Brunei	0.04	90.12	5.34	3.02	1.48	100	461.63	0.82	564.48	44.68	56.18
Egypt - Idku	0.02	95.31	3.58	0.74	0.34	100	437.38	0.76	578.47	41.76	54.61
Egypt - Damietta	0.02	97.25	2.49	0.12	0.12	100	429.35	0.74	582.24	40.87	54.12
Equatorial Guinea	0.00	93.41	6.52	0.07	0.00	100	439.64	0.76	578.85	41.95	54.73
Indonesia - Arun	0.08	91.86	5.66	1.60	0.79	100	450.96	0.79	571.49	43.29	55.42
Indonesia - Badak	0.01	90.14	5.46	2.98	1.40	100	461.07	0.82	564.89	44.63	56.17
Indonesia - Tangguh	0.13	96.91	2.37	0.44	0.15	100	431.22	0.74	581.47	41.00	54.14
Libya	0.59	82.57	12.62	3.56	0.65	100	478.72	0.86	558.08	46.24	56.77
Malaysia	0.14	91.69	4.64	2.60	0.93	100	454.19	0.80	569.15	43.67	55.59
Nigeria	0.03	91.70	5.52	2.17	0.58	100	451.66	0.79	571.14	43.41	55.50
Norway	0.46	92.03	5.75	1.31	0.45	100	448.39	0.78	573.75	42.69	54.91
Oman	0.20	90.68	5.75	2.12	1.24	100	457.27	0.81	567.76	43.99	55.73
Peru	0.57	89.07	10.26	0.10	0.01	100	451.80	0.79	574.30	42.90	55.00
Qatar	0.27	90.91	6.43	1.66	0.74	100	453.46	0.79	570.68	43.43	55.40
Russia - Sakhalin	0.07	92.53	4.47	1.97	0.95	100	450.67	0.79	571.05	43.30	55.43
Trinidad	0.01	96.78	2.78	0.37	0.06	100	431.03	0.74	581.77	41.05	54.23
USA - Alaska	0.17	99.71	0.09	0.03	0.01	100	421.39	0.72	585.75	39.91	53.51
Yemen	0.02	93.17	5.93	0.77	0.12	100	442.42	0.77	576.90	42.29	54.91

[1] Calculated according to ISO 6578 [T = -160°C]. [2] Calculated according to ISO 6976 [0°C / 0°C, 1.01325 bar].

Fig 9-2. Typical composition of LNG worldwide

9.3 Example of odorisation system for L-CNG station

LEWA DA7 with odoriser tank of 25÷50 litres; diaphragm pump type MLM; manometer 300 bar mounted on output valve; power and control p.c.b OLK7; intake Ex-p.c.b. ExOT7-4.

9.4 Example of cryogenic road tanker for LNG (INDOX cryoEnergy) and cost vs benefit analysis

Main features

- Transportable product: approval for LIN-LOX-LAR-LNG
- Optimization for LNG
- Regulation/norms: ADR / TPED / DOT / IMO (optional)
- Total nominal volume: 50,000 to 54,000 liters
- Type: trailer
- External diameter: 2480 to 2545 mm
- Total length: 14.000 mm
- Maximum height: 3,900 mm
- Dead weight approximately: from 12,600 to 14,250 kg
- Tractor weight: 6,800 to 8,250 kg
- Pay load: from 20,600 to 21,500 kg

LNG transfer system

- Upload / download by differential pressure
- Self charge with pump
- Charge / discharge with pump
- Pump pre-cooling circuit
- Pressurization circuit
- External pressurization circuit (optional)
- Locker in a central or rear
- Hydraulic or electric pump drive

Safety System

- Venting system of the internal pressure
- Manual circuit vent
- Purge system of piping
- Grounding
- Control system (level, pressure, weight)
- Control system of the vacuum of the isolation chamber
- System of limitation of the maximum filling
- Emergency stop
- Locking system of the brakes during discharge
- Security system in case of capsizing
- depressurization of the system in case of capsizing

Inner tank

- Material: stainless steel
- Max service pressure: 3 - 7 bar
- Design Temp.: - 196ºC
- Thermal insulation system: vacuum + perlite + mineral cryogenic whool
- Safety valve sas per norms

Outer tank

- Material: Carbon steel / stainless steel

	DIESEL	LNG	DUAL
LNG extracost	0,0	21.000,0	30.000,0
Sustitution	0,0	100,0	55,0
Diesel consumption	34,0	0,0	15,0
Gas consumption	0,0	30,0	13,0
Anual fuel cost	55.080,0	32.400,0	38.340,0
Savings €/ 100km	0,0	15,1	11,2
Amortization (years)	0,0	0,9	1,8
Amortization (km)	0,0	138.888,9	268.817,2
Anual savings		22.680,0	16.740,0

Fig 9-3. example of cost vs benefit analysis of a LNG truck