GOOD PRACTICE EXAMPLES - APPENDIX D
LNG BLUE CORRIDORS PROJECT FACT SHEET

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This deliverable contains original unpublished work except where clearly indicated otherwise.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.

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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.

2. Types of stations

The results presented in this document refer to a variety of different filling station configurations, including LNG and LNG/L-CNG stations in permanent and mobile arrangements. Stations can dispense gas exclusively in either liquid (LNG) or gaseous form (L-CNG), or both (LNG & L-CNG). At minimum, all stations in this project offer liquid refueling. While the ability to dispense both LNG and L-CNG is desirable from technical and environmental perspectives, since both CNG and LNG vehicles can be serviced and boil-off gas from LNG can be handled safely without venting to the atmosphere, the higher upfront investment cost for this setup is a negative factor. On the other hand, constructing a station that dispenses both fuel types can sell fuel to more vehicles, potentially shortening the return on investment.

Each of these station types can be implemented in permanent, mobile, or semi-mobile configurations, and each type offers different costs and benefits. Permanent stations tend to be the most technically advanced and can support higher vehicle traffic. However, because they carry higher upfront costs and cannot be easily relocated once constructed, they carry a higher investment risk.

Mobile filling stations operate without any permanent infrastructure other than an electricity source. The ability to operate this type of station virtually anywhere makes it an especially attractive option in regions where demand for LNG is not yet established, and the lower cost and ability to move to areas of high demand lowers the investment risk. However, refueling takes longer than with a permanent station, only one truck can be refueled at a time, and the smaller storage capacity can require more frequent LNG deliveries if demand is high enough, making logistics complicated and expensive. This is the reason why all those who have invested in the station's construction will build a permanent one.

The third configuration, semi-mobile, can be utilized as either a temporary solution or as long-term infrastructure. This layout combines a mobile LNG storage tank with one or more permanently fixed fuel dispensers in a modular format (the permanent dispensers and their associated wiring/piping can be installed or removed in 1-2 days) that can be implemented with either LNG or LNG & L-CNG, and offers faster filling times compared to a normal mobile station. However, fuel storage capacity is limited compared to a permanent station, and costs are higher and mobility is compromised compared to a 'normal' mobile station. No partners plan to implement this type of station.

The ideal setup for each partner ultimately depends on current and predicted demand for LNG and on the status of the technology in each individual country. Countries that already have a sizeable fleet of LNG trucks and offer some LNG refueling infrastructure have already established travel routes and traffic patterns, making it easier to determine a viable location for a permanent station.

2.1 Dimensions and Capacities

The partners provided details regarding the LNG storage capacity, nozzle type, pump performance, and dispensing pressure. They also gave details about L-CNG dispensing, including the CNG buffer 'ready fill' storage capacity (see figure below, item number 14: CNG buffers) and the compressor performance.

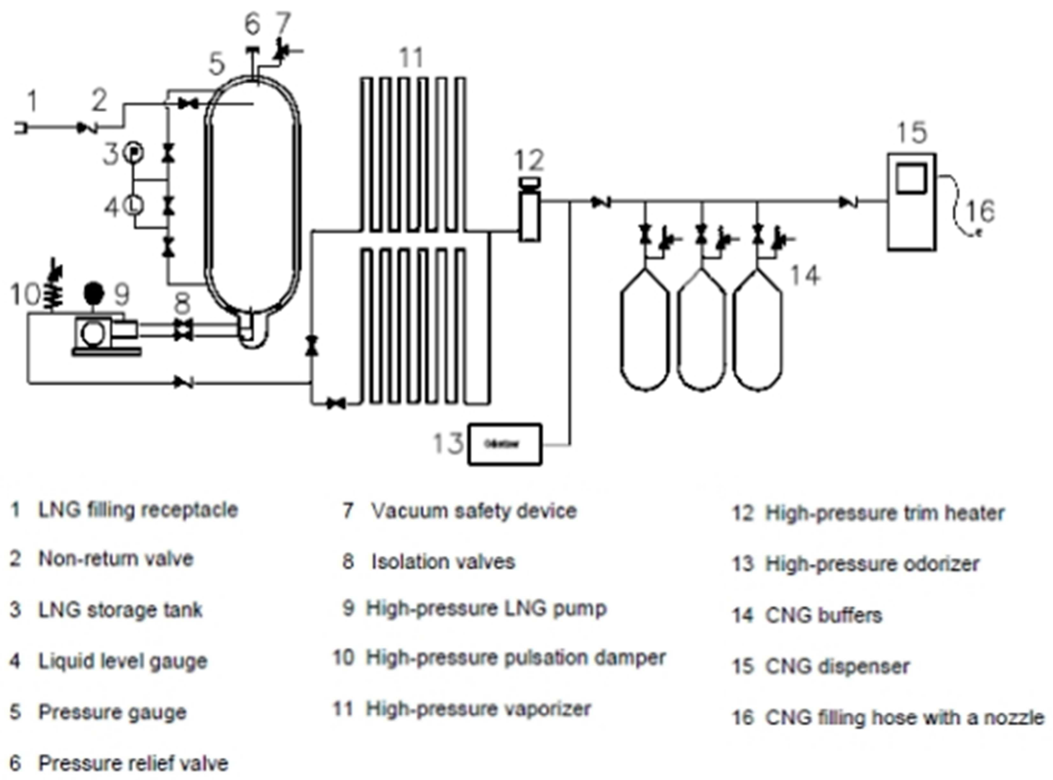

Figure 1-2 Schematic diagram of an L-CNG station

In all, partners kindly share information about:

- Total LNG capacity
- Expected source of the gas
- The number of LNG fuel dispensers
- Will a cryogenic pump be included?
- Max LNG flow rate
- LNG dispensing pressure (indicating if adjustable)
- LNG fueling nozzle type
- LNG vent-back nozzle type
- Number of L-CNG dispensers (if applicable)
- L-CNG compressor performance (if applicable)
- Amount of 'ready fill ' capacity for CNG storage (if applicable)

Table 2-1 LNG stations technology

Company	*DRIVE (Antwerp)*	*ENI (Piacenza)*	*ENI (Pontedera)*	*GALP (Porto)*	*GALP (Sines)*	*German station*	*GNF (Barcelona)*	*GNVERT (Rugnis)*	*GNVERT (Lyon)*	*GNVERT (Nimes)*	*Dourogas (Elvas)*	*Dourogas (Lisbon)*	*SGA (Örebro)*
Total LNG storage capacity	70m^3 tank	60m^3	100m^3	60m	80 m^3	Tbd	60m^3	60m^3	60m^3	80m^3	10m3	60m^3	61m^3
Expected gas source	Zeebrugge	Barcelona Fos Tonkin	Barcelona Fos Tonkin	TGNL de Sines	TGNL de Sines	Tbd	Barcelona	Manoir de bretagne, Zeebrugge	Manoir de Bretagne, Fos Tonkin	Manoir de Bretagne, Fos Tonkin, Barcelona	TGNL de Sines	TGNL de Sines	Nynäshamn
Number of LNG dispensers?	1	1	1 + 2 optional	1	1	Tbd	1	1 + 1 later	1	1	1	1	1
Cryogenic Pump? (Y/N)	Y	Y	Y	Y	Y	Tbd	Y	Y	N	Y	Y	Y	Y
Max LNG flow rate:	65 kg/min	60 kg/min	60 kg/min	80 kg/min	80 kg/min	Tbd	30 kg/min	65 kg/min	65 kg/min	65 kg/min	50 kg/min	50 kg/min	60 kg/min
LNG dispensing pressure	7-10 bar	8 bar	8 bar	8 & 16 bar	8 & 16 bar	Tbd	8-16 bar	8 bar	8 bar	8 bar	9-13 bar	9-13 bar	8 bar
LNG dispensing nozzle	JC Carter	JC Carter	JC Carter	JC Carter	JC Carter	Tbd	JC Carter	JC Carter	JC Carter	JC Carter	JC Carter	JC Carter	JC Carter
Vent-Back nozzle	Macrotech (1/2")	Macrotech (1/2")	Macrotech (1/2")	Y	Y	Tbd	Macrotech (1/2")	Macrotech (1/2")	Macrotech (1/2")	Macrotech (1/2")	Macrotech (1/2")	Macrotech (1/2")	Macrotech (1/2")
Number of L-CNG dispensers	1	1	2	1	1	Tbd	1	1 + 1 later	1	1	1	1	1
L-CNG: Compressor Performance	700 Nm^3/h	1350 Nm^3/h	1350 Nm^3/h	415 Nm3/h	415 Nm3/h	Tbd	800 Nm3/h	800 Nm3/h	800 Nm3/h	800 Nm3/h	400Nm3/h	400Nm3/h	700 Nm3
For L-CNG: Planned CNG storage	2400 liters	2400 liters	2400 liters	2560 liters	2560 liters	Tbd	2800 liters				1600 liters	2400 liters	2100 liters

Glossary	
Planned total capacity	Planned total LNG capacity for each station
Expected gas source	LNG terminal that will supply fuel to station
How large a reserve capacity is needed to cover this transport time?	Estimate, based on 'total kg gas/week' (see sec. 3.1)
How many storage tanks?	Number of cryogenic LNG storage tanks to be implemented
Number of LNG filling pumps?	Number of LNG dispensers for transferring fuel to trucks
Cryogenic Pump? (Y/N)	Will station be equipped with a cryogenic pump (yes/no)?
Estimated maximum # trucks/hour	Expected system demand – provides a measure of the usage demand for the station's mechanicals
Number of L-CNG dispensers	Number of CNG dispensers at each station (if applicable)
For L-CNG: Compressor Performance	Maximum system throughput per hour – a measure of CNG compressor performance
For L-CNG: How much 'ready fill' capacity will be built into the station (CNG storage)?	The amount of CNG that can be held at dispensing pressure (200+ bar). Provided in L or m3

3. Strategies for implementation

3.1 Technology and final locations

The data presented was gathered by survey over weeks. Each partner was requested to provide the planned station location, station type (LNG or LNG/L-CNG; permanent or mobile), estimated probability of implementation, the estimated timing for implementation, and some brief comments describing the scenario.

A map including the locations of all BC LNG stations in addition to all known existing LNG stations is also included below. The planned Blue Corridors locations are indicated by a blue marker; the already existing LNG stations are noted by a green marker; those undefined are indicated by red marker. Most of the data for the existing LNG stations was obtained using industry records, along with contributions from project partners.

All sites were selected based on the original locations presented in the project's proposal. Any deviations were justified.

All results indicated in this deliverable are current as of the time of writing.

Result

Table 3-1 LNG stations status and glossary

Participant	Corridor	Nearest BC station	Address/location	Location confirmed?	Process Stage	Timing for Implementation
DRIVE	WE-BLUE	Rungis to 310 Km	Steenlandlaan 3, 9130 Kallo - Antwerp, Belgium	Y	In service	In service
DRIVE	WE-BLUE		Brussels Airport	Y	unknown	unkown
ENI	Med-BLUE	Lyon to 390 Km	Via Caorsana N. 41, 29100 Piacenza, IT	Y	In service	In service
ENI	Med-BLUE	Piacenza to 180 Km	Area Servizio Pontedera Nord, Livorno, IT	Y	Construction	Q1 2016
To confirm	WE-BLUE		Germany, Location to confirm	N	Companies looking for fleet operators	unkown
GALP	ATL-BLUE	Carregado to 240 Km	Matosinhos/Porto(A4 km 3,8) ,PT	Y	Built	Q1 2016
GALP	ATL-BLUE	Carregado to 120 Km	Port of Sines, PT	Y	Construction	Q1 2016
GNF	MED-BLUE	Nymes to 320 Km	Calle Guifré el Pelós 10, Santa Perpetua de Mogoda, Barcelona, Spain	Y	In service	In service
GNVERT	SONOR-BLUE	Nymes to 220 Km	Lyon, FR	Y	Construction	Q2 2016

GNVERT	SONOR-BLUE	Antwerp to 310 Km	Rungis (Paris), FR	Y	Ready	In service
GNVERT	ATL-BLUE	Lyon to 220 Km	Nîmes, FR	Y	Ready	In service
GOLD	ATL-BLUE	Sines to 120 Km	Estrada Nacional N1 Carregado (placa norte) (Lisboa), Portugal	Y	In service	In service
GOLD	MED-BLUE	Carregado to 160 Km	Elvas, Portugal	*Y*	Construction	Q1 2016
SGA	SoNor-BLUE	Antwerp to 1080 Km	Örebro, Berglundavägen 1B, Pilängen	Y	In service	In service

Glossary			
Participant	Name of project partner	**Process Stage**	Either: 'Exploring' (assessing a location's viability); 'Planning' (designing the technical layout of the station); 'Pending approval' (waiting for approval of station design/location from local or national authorities); 'Project approved' (location approved, but not yet under construction); 'Construction' (station is under construction); 'In service' (station is in operation)
Corridor	Which of the four Blue Corridors the station will be built along. Either: SONOR-BLUE (North-South corridor, ATL-BLUE (Atlantic Corridor,; MED-BLUE (Mediterranean Corridor), or WE-BLUE (West-East corridor)	**Timing for Implementation**	Expected date when fueling station will be operational.
Station Type	LNG: Station will only dispense LNG fuel LNG/L-CNG: Station will dispense both LNG and L-CNG Permanent: Station will have a permanent, immobile infrastructure Mobile: Non-fixed mobile station will be implemented Semi-Mobile: Station will have permanent dispensers fixed in one location, but will feature modular, mobile storage tanks.	**Notes**	Any comments provided by partners to accompany the data provided here

Address/location	Street address and/or GPS coordinates of the planned LNG fueling station	**User Initials**	Initials of partner who provided the data for this deliverable
location confirmed	Whether or not station will definitely be constructed at this location (related: 'Estimated Probability for Implementation')		

Figure 1-3 Map showing planned (blue), in service (green) and not confirmed (red) LNG stations

As shown above, all of the partners will construct permanent stations. Additionally, all partners plan to implement stations that will dispense LNG and L-CNG at permanent stations. Despite higher upfront costs, this setup is desirable because:

- The station's revenue potential grows by servicing CNG cars and trucks in addition to LNG models.
- Some LNG trucks comes factory-equipped with CNG backup tanks. It is beneficial to be able to refill the CNG cylinders as well.
- L-CNG systems provide a mechanism to safely transfer boil-off gas from LNG storage tanks into CNG storage, rather than venting gas directly to the atmosphere. This improves environmental performance and maximizes revenue from what would otherwise be a waste product.

3.2 Reasons for choosing location

The goals of the project (to develop a network of LNG fueling stations to allow for Trans-European, long-distance heavy duty vehicle transportation using natural gas) must be aligned with the present reality, which is that nobody will construct a filling station in a location without consistent demand from LNG trucks. Some stations were relocated to better match traffic flow patterns and to better serve important fleet operators or logistic centers. Once a basic infrastructure is implemented that allows major operators to purchase and implement LNG trucks, the gaps can be filled in. Nevertheless, travel between all stations will still be possible with the release of trucks with longer driving ranges.

Geographical considerations have also affected the final locations of the stations. Because the LNG trucks that are available early in the project have low power outputs, and mountainous regions, especially when towing heavy loads, are especially challenging. For example, many of Germany's proposed locations are in hilly regions, which disqualifies them from consideration at this time. As higher-power mono- and dual-fuel trucks become available, some of these locations might be developed.

These are the different reasons based on which LNG facilities have been located where they are today in each market.

- Spain: The station that has been implemented in the LNG Blue Corridors project is located nearby Barcelona, in Santa Perpetua de la Mogoda. The LNG station is situated 2.6 km from the AP-7 motorway The decision about why this place was selected is justified because there is particularly high demand for LNG fuel in the Catalonian region of Spain, which borders with France, and the AP-7 is the main Motorway which connects the whole Mediterranean Corridor from Valencia to France, and this location provides important connections to the stations in France and Italy along the MED-BLUE Corridor.
  The following map shows the traffic overview of Barcelona. The average daily intensity of traffic is marked with different colours. The station is marked by a yellow dot.

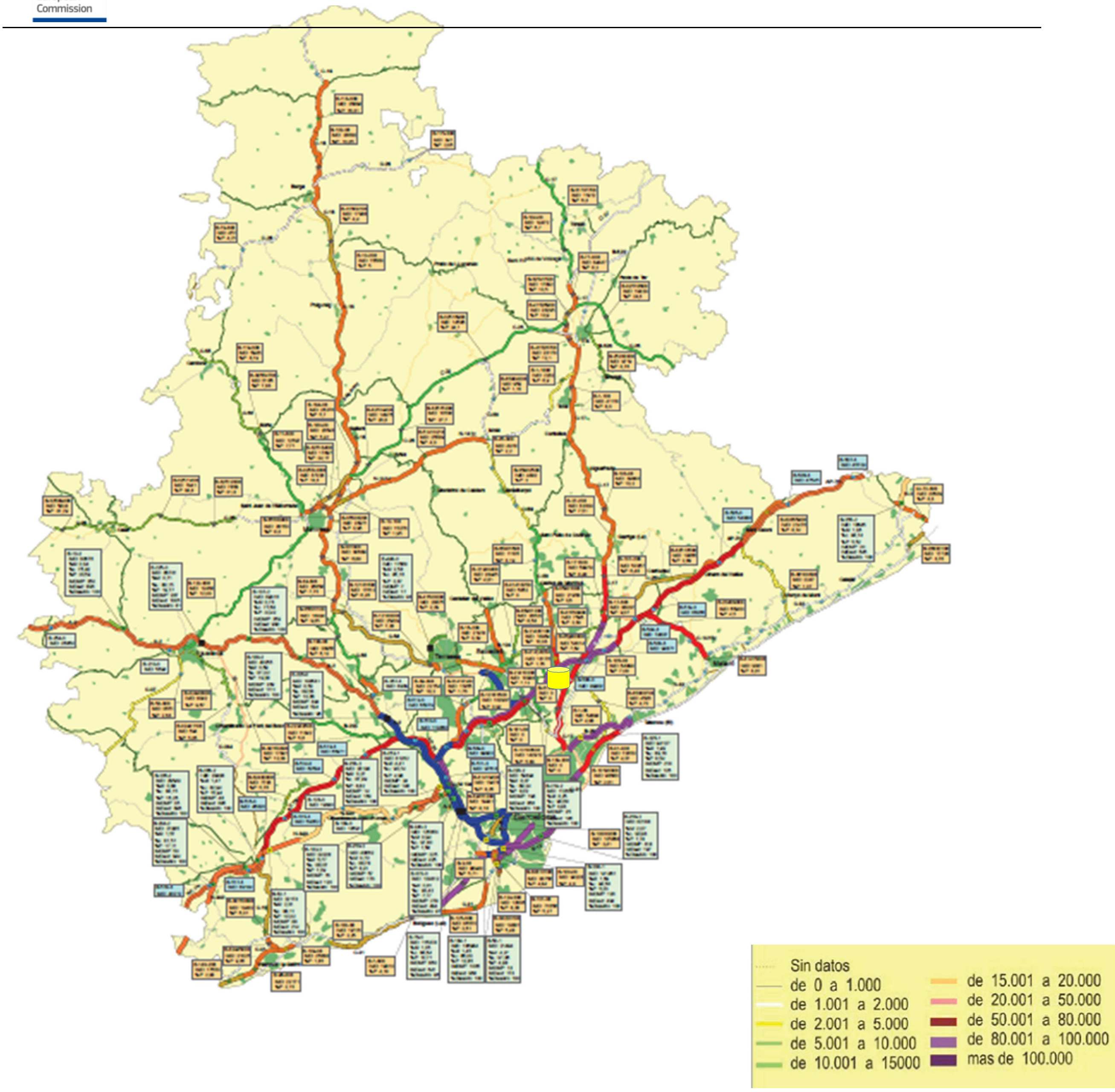

Figure 1-4 Map showing the traffic in Barcelona roads

As said, it is strategically well situated, close to highways which are passed by more than 100,000 vehicles daily on average, of which nearly 8 % are Heavy-Duty vehicles.

It is also important to mention that the logistics factors when it is time to transport LNG are a quite important variable, mainly in terms of costs. In the Barcelona station case, its proximity to the LNG Terminal located in the Barcelona port (35 km away from the station), makes it be a really good region to build the facility.

- Italy: Livorno (Pontedera) was chosen over other proposed locations due to a strong customer base and industry presence there, existing LNG-related activities in the port of Leghorn, compliant local administration, and most importantly, a direct connection with ferry traffic to/from Barcelona. In addition to traveling by land, LNG trucks will travel by boat between Barcelona and Livorno, thus opening a new pathway along the Mediterranean corridor. Trucks will travel from there on to Rome.

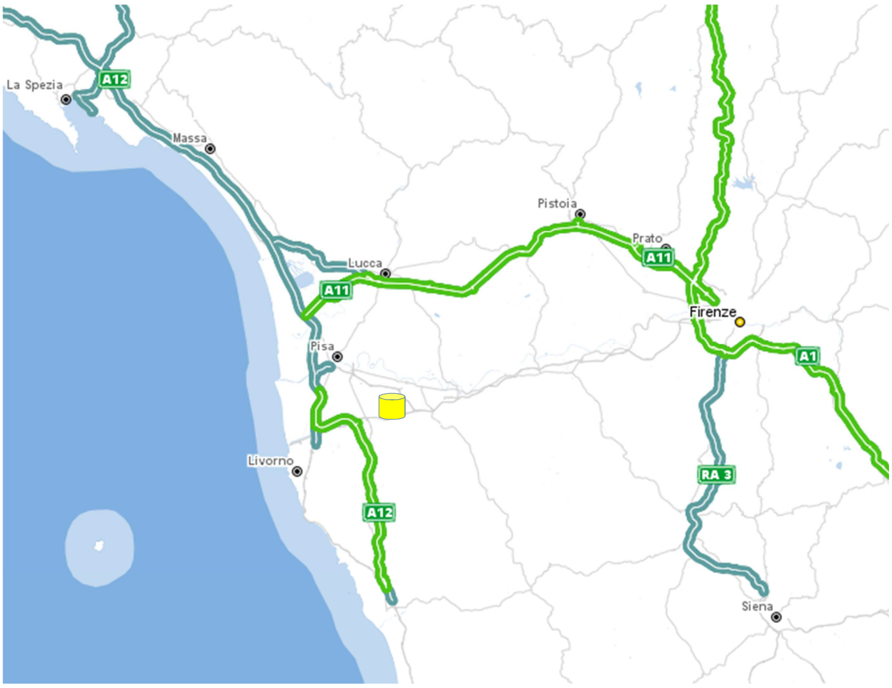

Figure 1-5 Map showing the location of the second italian LNG station in the Blue Corridors

The other LNG station in Italy is located in Piacenza, in a really good location since it is an area of junction of two main highways: The A1 that connects Milan to the middle region of the country, toward to Bologna, and the A21 road that connects Brescia to Turin, surrounding Milan, an area frequented by trucks due the high number of industrial activities.

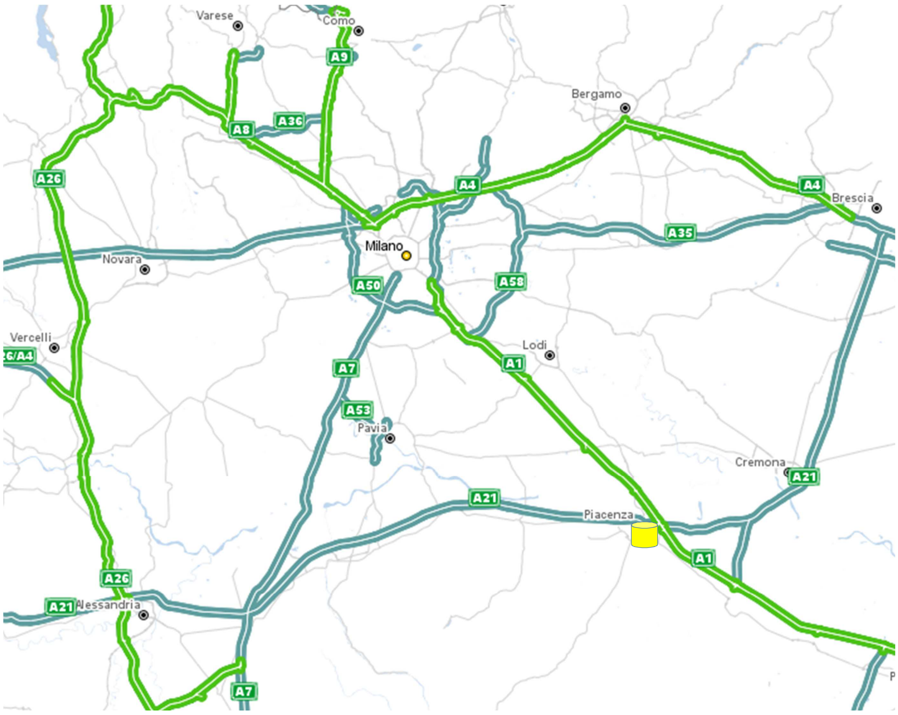

Figure 1-6 Map showing the location of the first italian LNG station in the Blue Corridors

The facility is situated less then 5 km away from these two main national and regional routes.

In both maps shown above, the green lines represent those highways highly frecuented; the blue lines mean a medium intensity of traffic.
As in the Spanish case, the LNG terminals' position plays a very important role when choosing the station location. The two LNG Italian facilities will be fed by the Barcelona and Fos Tonkin terminals.

- France: The three locations in France were selected based on a similar criteria to the rest of markets, that means taking into account the clients' routes, and also evaluating what the connectivity was with the national LNG terminals in order to evaluate possible logistic costs.

The French facilities (specially Lyon and Nimes) play a significant role within this corridor. The current distance between LNG stations, are in most cases, difficult to be covered by LNG trucks, assuming an autonomy of 800 km on average. Thanks to both stations, it will be easier to cross France by driving a LNG truck to get to both the north part of France and Italy. Again, their nearness to the LNG terminals in Barcelona and Fos Tonkin has been an important factor as well.

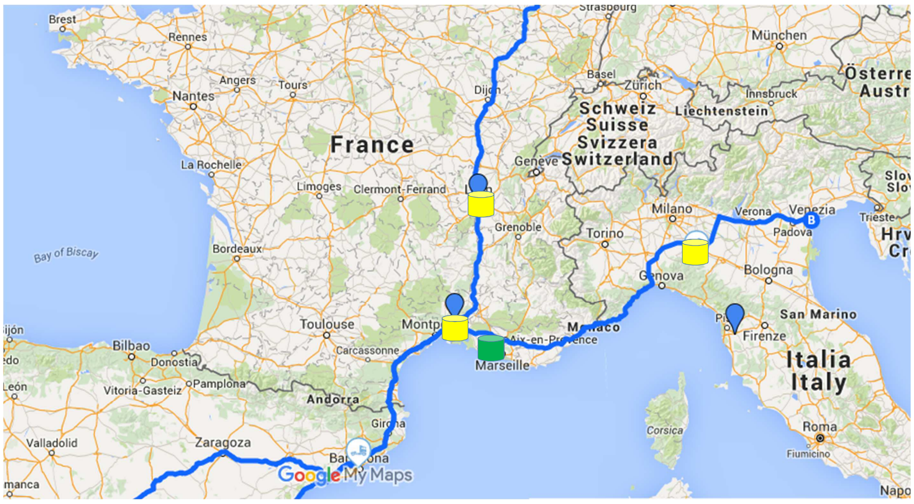

Figure 1-7 Map showing the connection in the Mediterranean corridor.

LNG stations are marked in yellow. The blue line corresponds the typical European route done by trucks, that connects Barcelona to Milan/Turin and to Lyon/Benelux area. The LNG terminal is coloured in green, as said, quite near stations.

The Rungis station is located relatively close to the main leaving highway of the city, namely the A.6. In turn, there are many important roads that surround Paris that are really close to the station. The Rungis area is a well known logistic location frequented by trucks and is a crossing point for those who transport goods to the south.

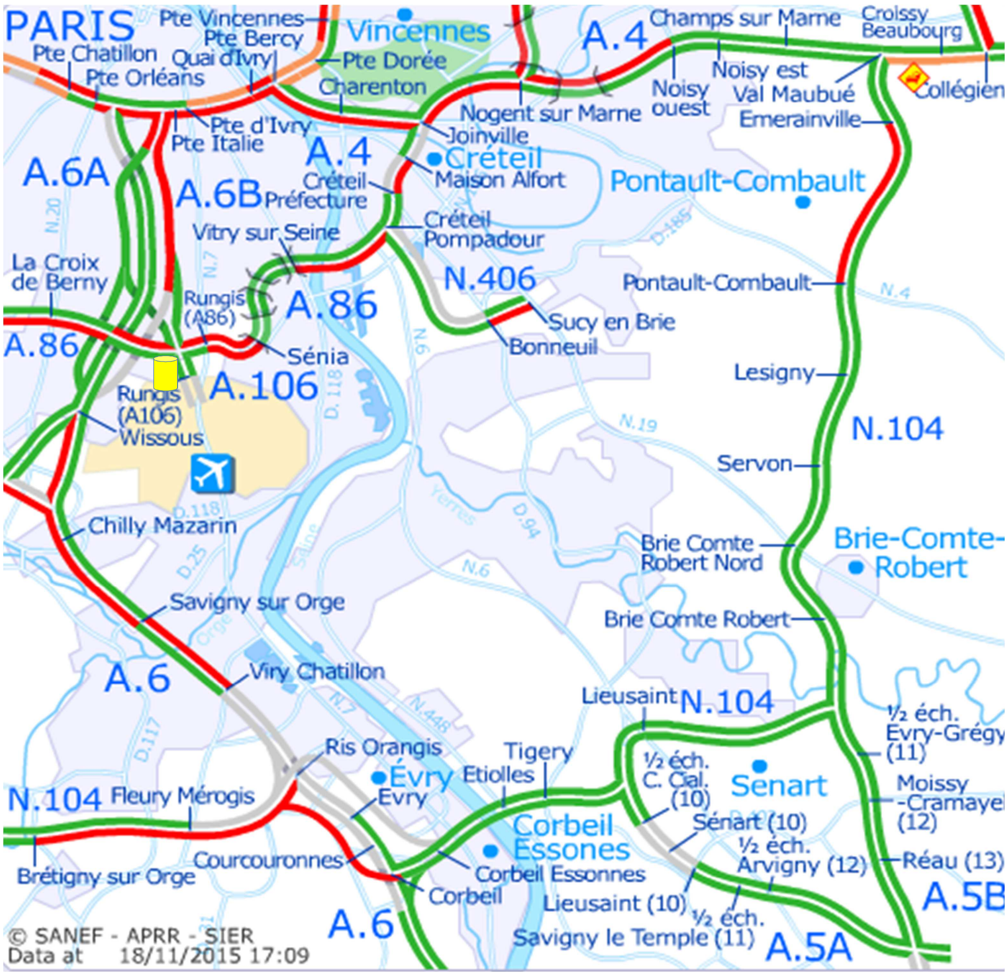

Figure 1-8 Paris roads. It is zoomed the south city area.

The roads marked in red and green correspond to the high and medium rate of vehicles per road, respectively.

- Portugal: Currently the distance between Sines and Barcelona can hardly be covered but it will be easier once the Elvas stations are working, since it will make the journey 150 km shorter. In general, the Portuguese stations are close to the main routes used to enter and leave the country, with all the facilities needed. All in all, the stations have a stategic location.
  One station will already be built in Lisbon, in line with the Project proposal. Sines is home to more LNG truck traffic and activity than Faro, and is also home to an LNG terminal. Building four stations enhances the geographic distribution of the stations within Portugal.

- Belgium and Sweden: the factors analysed in both countries are again quite similar to the prior ones. The following criteria were important for the choice of the final location of our station:

· Accessibility from major highway (distance to highway, HD traffic on that highway). The Orebrö station is located precisely at the junction of E18 and E20 roads. This is particularly important since they connect Stockolm to Göteborg, quite frequented by trucks.

In the Belgium station, located in the port of Antwerp: several trucks are passing by this point with many possible different destinations, toward UK, The Netherlands – where there is already a good LNG national network, Paris, etc.

· Close to logistic hub (such as port or distribution centre), potential future volume.

· Presence of launching customer for base volume. Technically it is needed to have about 500 kg/day (4-5 trucks) to avoid boil-off, slightly more if the station also delivers L-CNG. This is the minimum demand from day one. As an average rule of thumb 20 trucks which will generate a sales volume of 500-600 tons/year are sufficient for a station.

· Absence of other LNG station (not too hard, for the time being)

· LNG Compatibility of site with respect to permit (environment, safety, noise).

· CNG potential on that location.

In addition, the Zeebrugge and Nynäshamn LNG terminals are well situated, logistically speaking, (80 km and 160 km respectively).

4 Conclusions

The differences in progress among partners in the LNG Blue Corridors project mirror prior experience in development of LNG as a transport fuel in the participating member states. Countries such as Spain, Portugal, Italy, and Belgium/Netherlands generally have more experience with LNG, and the representatives from these nations have generally progressed much further with their stations.

Confirming station locations has been challenging in counties lacking a preexisting political or economic framework for LNG as a fuel. In some countries, particularly France, challenges and delays in obtaining regulatory approval has slowed progress. Most of all, market conditions have been a limiting factor. Weak demand for alternative fuel transportation solutions and limited vehicle offerings (only 330 horsepower) have slowed developments. This is true in Germany, where limited vehicle offerings and uncertain long-term cost savings (due to unclear taxation policy) is delaying progress. In order to manage financial risk, companies need to secure a cooperating fleet operator before committing to a particular location for their filling station.

In addition, sales volume requirements depend very much on original capital expenditure and commercial LNG and L-CNG margins. Costs for pure LNG and L-CNG vary considerably. Implementation of LNG on existing CNG or traditional fuel stations presents an entirely different business case due to preexisting equipment and land ownership. This makes every project quite a case of its own.

As a common variable in all EU markets, companies need to install LNG equipment at already existing stations in order to take advantage of the auxiliary facilities. This is important since some companies do not have LNG stations in property, so they have to look for locations and carry out long commercial activities with the owner oil company.

Moreover, in many cases it is important to be updated about the state of the legal situations of each station, in order to start then the legal procedure by the owner company. Very often this leads to important delays and even the rejection of the construction.

The location destined to install the LNG station requires wide space. This factor makes the construction more difficult because of the presence of another station, whether in terms of safety distance or truck maneuverability.

Depending on the location of the station, the procedure to get working permits may vary. There are temporary working licenses of 3 months if the approval just depends on the town hall, or they could be even one year, if the community authorities are involved.

Partners