**GNVERT/GDF SUEZ PROMOTES LNG AS A FUEL FOR HEAVY TRUCKS IN FRANCE BY PARTNERSHIP WITH TRUCK MANUFACTURERS**

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**ABSTRACT**

GNVERT concludes a partnership with Transports P. Mendy, a French transportation company, and IVECO France, performed in November 2011 the first French tests under operating conditions of heavy vehicles running on Liquefied Natural Gas; Tests on a Volvo dual fuel truck foreseen beginning 2012. Testing program on 3 weeks and running 9000 km with LNG Results: Truck autonomy up to 600 km with one fuel tank of 570L, No incident, LNG consumption lower than expected (35 kg/100 km), Zero particulate, Nox very low, 25% reduction CO2, 50% reduction noise & vibration LNG filling in 5 minutes Over actions: Investment in the first LNG filling station, Initiated partnership contacts with Westport, Renault truck, Chart and Cryostar, Involved in the European program to develop the concept of European LNG blue corridors Market forecast of 9 000t/yer with 18 L-CNG filling stations in 2017

1. **INTRODUCTION/BACKGROUND**

The transport area is consuming 30% of the world energy and this energy consumption is mainly depending on oil. The transport sector is the first contributor of GHG emission and local pollutants. Local pollutants are identified as Invisible killers and more precisely PM (Particulate Matters) that are responsible of 42,000 untimely deaths per year in France.

Therefore environmental focus is more and more stringent and solutions developed at a local scale are the best to solve the 2 constraints that are depleting air quality:

- GHG emissions
- Local pollutants (PM, NOx, SOx…)

LNG as a fuel and its renewable form liquefied Bio-methane, is the best solution to cope with the dilemma of GHG and local pollutants linked to the transport sector. LNG as a fuel can cover the widest mobility range from urban transport to medium and long haul transport and from light vehicles to heavy vehicles.

Global NGV market is growing, and it is foreseen new technologies, regulations, government strategies to be developed and introduced. The development that anyone is witnessing is strongly based on two key parameters:

- Gas abundance, according IEA (International Energy Agency), we are entering the golden age of gas. This new map, with abundant resources required higher value market, thus the fuel market is the perfect target. NG has today a worldwide sourcing, not linked with the oil production and its geopolitical conditionings. The discovery of new and huge NG reserves, from both traditional wells and also shale gas, is multiplying the producing sites and strongly increasing the known reserves.
- Environmental constraint and more specifically air quality in big cities. On one hand worldwide, people are more and more concentrating in cities where mobility is a key factor for the development. And the other hand air quality is depleting quicker than the growth of the city. In some cases, for
example Beijing, the dangerous urban air quality forces local authority to take strong actions in order to mitigate the risk. Natural gas and more precisely LNG appeared as a key component to achieve sharp improvements.

LNG appeared to be the only real alternative to oil derived fuels, applicable to heavy trucks as it is affordable, economical and all its related technologies are mature and well known. The transport of NG from production sites to the users is flexible. It has been made in first place through pipelines, whose network grows continuously. Nowadays, LNG is the other way of transporting natural gas, giving a great flexibility to the market that approaches the oil market case, in which the big LNG ship carriers are able to go from any producer to any final customer with LNG terminals.

Switching from diesel to LNG for heavy duty vehicles substantially reduces carbon dioxide emission and reduces Green House Gases (GHG). NG is the cleanest fossil fuel. The high hydrogen content of the methane molecule (CH4) compared to any other hydrocarbon based fuel, allows a substantial reduction of the carbon dioxide emissions. All WTW analysis for GHG emissions from NG when used as a fuel for vehicles are favourable when compared to conventional fuels. Furthermore, the renewable natural gas Biomethane (same molecular composition) can be mixed in any percentage with natural gas, both as CNG and LNG. This opens the way to increase the percentage of renewable fuels in transport.

Compared to Diesel, NG engines are more efficient in terms of local pollutants. They generate significantly less Particulate Matter (PM) and nitric oxides (NOx). NG engines already fulfill the EEV exhaust emission standard (a step forward from Euro V) without complicated exhaust after treatment technologies that will be required for diesel engines in order to meet Euro VI. When after-treatment technologies are taken into account NG engines have a better overall value chain efficiency than conventional diesel engines. Next to local pollution, noise emissions, caused by traffic are responsible for a lower life quality due to stress, cardiovascular diseases and sleeplessness, NG vehicles reduces noise emission significantly improving life quality around road traffic area.

The European Commission adopted in March 2011 a comprehensive strategy (transport 2050) for a competitive transport system set out to remove major barriers and bottlenecks in many key areas across the fields of transport infrastructure and investment, innovation and internal market. Methane is part of this strategy for a cleaner transport with lower oil dependency. Therefore, European Commission officially introduced a demonstration project for heavy duty vehicles running with liquefied methane to promote LNG blue corridors on medium and longer distances. This development is linked to the growing availability of LNG in more and more points of Europe that is consequently, opening the way to use it in the heavy on road, medium and long distance transport. Finally, it reduces Europe’s dependence on liquid oil based fuels and particularly in diesel oil that Europe is importing because of the unbalance - petrol to diesel - produced in the refineries and market demand. Europe is actually exporting gasoline and importing diesel.

Since 2011, French Government is actively supported LNG as a fuel for maritime development. This support is also looking how maritime project could help the development of road LNG projects by direct synergy: LNG access, bunkering, regulation, taxation...

GDF SUEZ, benefiting from the 15 year experience of GNVERT in the field of sustainable mobility with Natural Gas as a fuel innovates since 2011 in the emerging LNG fuel market and supports the development of LNG chain distribution which is for the end users environmental-friendly, fully renewable, safe, reliable and competitive.

GNVERT is a subsidiary of GDF SUEZ Energy Services, European and global leader of multi-technical services, one of GDF SUEZ Group’s six Business Lines (Energy Services: 80,000 employees, revenues of EUR 14 BN) and GDF SUEZ Energy Europe (Revenues of EUR 41 BN).
GNVERT, cross-Group sustainable mobility operator, is the main player in the Natural Gas Vehicles (NGV) fuel sector in France.

2. OBJECTIVES OF THE PAPER

This paper is illustrating how GNVERT, has initiated and it is developing LNG in France and Europe. The promotion of LNG as a fuel was initiated in France by GNVERT thanks to:

- The expertise of GDF SUEZ on LNG: infrastructures, engineering for design and safety, sourcing
- The collaboration with truck manufacturers: IVECO and VOLVO

To launch the development of LNG as a fuel in France from null, it is necessary to aggregate the critical mass of experience: know-how, expertise, industrial parties and stakeholders in LNG transport and infrastructure technology. It involves cooperation between heavy duty vehicle manufacturers, fuel suppliers, fuel distributors and fleet operators.

The strategy was to work closely with each stakeholder: OEM’s, Gas Company, Institutions, Customers, equipment suppliers, in order to achieve industrial trials and demonstrate the technical and economical viability of the solution.

Thanks to these demonstrations, it could be easily underlined that the state of art fully cope the need of final customers and that environmental performances are achieved.

The objective for OEM’s (VOLVO and IVECO) was to demonstrate the potential of the powertrain and vehicle technology: dedicated spar-ignited for IVECO and dual fuel for VOLVO. The following parameters where closely monitored:

- Fuel quality aspects to optimise the use of LNG for HD vehicles;
- Low temperature efficient after-treatment systems for heavy duty natural gas engines, to abate in particular NOx and unburned methane emissions for lean burn engines (lambda >1.5) at temperatures below 150ºC as well as for stoichiometric engines (lambda =1 ) using 3-way catalysts, to comply with post-Euro VI requirements (considering the new WHTC and WHSC);
- Utilization of measurement systems to demonstrate the compliance of the emissions as well as the best practices to measure the low level of emissions emitted by the Euro VI/Post Euro VI engines;
- To evaluate energy efficiency in well to wheel study of the whole chain, taking into account different markets: regional or long haul transportation;
- Costs analysis from the point of view of the fleet operators – main expected clients of the Heavy Duty vehicles running on LNG;
- Durability of heavy duty engines, including its after treatment and of the vehicles running on LNG under different climatic, geographic and traffic conditions by demonstrations on real and different profiles.

For GNVERT, objectives were to assess the best development for LNG fueling station infrastructures and outlining the following criteria:

- Economical data in order to closely assess the business model of L-CNG stations depending on the different potential for combining LNG and CNG refueling infrastructure in terms of utilizing boil off for CNG purposes and to lower investment costs for LNG);
• Assessment of relevant national standard(s) especially different risk scenarios and required safety standards, which should be defined together with local authorities and institutions to increase the acceptance by early involvement and information supply;

• Definition of guidelines in order to ensure high safety standards for the refueling process and optimised cost efficiency for operations and maintenance.

Additionally the project focuses on further developments to satisfying (future) technical standards (e.g. Euro VI for LNG heavy duty vehicles) and to provide recommendations for harmonisation of standards and future common regulation in Europe to remove the existing barriers for heavy duty vehicles running on LNG.

3. DEVELOPMENT

Stakeholders

Identifying all stakeholders in France and Europe for the development of LNG as a fuel was firstly undertaken.

![Stakeholder diagram for LNG as a fuel development](image)

Figure 1: Stakeholder for LNG as a fuel development

OEM’s are key actors for the development of LNG as a fuel. GNVERT got contact with 2 of them that were sharing the strategy of development of LNG in France: IVECO and VOLVO.

IVECO began experimenting with CNG buses and trucks in the year 1994, and in 1995 began mass production and has managed to settle on two specific market niches: buses and urban solid waste collection. Commercially, Iveco has verified that the use of CNG has its limitations for use on long distances because of its limited range; around 350 km. To solve this problem, since 2004, IVECO has been working on LNG truck prototypes, developing new technology that increases the autonomy of natural gas vehicles up to 800-900 km. In 2005 the first pilot truck was put into service and it has been working since then at full capacity, although it is used for collecting solid waste. In 2010 a limited number of pilot LNG vehicles were introduced and are now covering local services primarily in Spain and the Netherlands. In 2011, IVECO started to look at the French market.
VOLVO, in 2007, with the objective of decreasing CO₂ emissions, has experimented 7 different technologies (LNG/LBG dual fuel, DME, synthetic diesel, ethanol/methanol, bio diesel, CBG/H₂ and CBG). Among, all these technologies LNG/LBG dual fuel was assessed to be one efficient and to be developed. In 2010, Volvo launched first LNG trucks prototypes on the Swedish and English markets. In 2011, Volvo France announced to address the French market.

GNVERT, got contact for LNG supply with several companies taking into account what were the nearest LNG terminal close to the LNG fueling station that is under project. According a map of LNG distribution, GNVERT assess LNG supply with GDF SUEZ from the terminal of Montoir (France) and Zeebrugge (Belgium) and Gas Natural from the terminal of Barcelona (Spain). For the “green” version of LNG: LBG, GNVERT got contact with GASREC.

For safety, design and engineering, GNVERT got support from GDF SUEZ and more specifically from the subsidiary ELENGY that has a long experience of the product and CRIGEN for the research and the determination of French regulations frame of the activity.

**Value Chain**

As for CNG since 15 years, GNVERT decided to be the main LNG fuel player and to act on each part of the value chain of the business model.

Therefore, for each customer, GNVERT is designing and building the fueling station either in a tailor made option or in a standard design according the customer needs. GNVERT is financing the whole solution. GNVERT is distributing NG as a fuel (CNG or LNG) and realises all the operations and maintenance either preventive or corrective.

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**Flexible solution**

NG as a fuel is a highly flexible solution that provides the best choice of mobility from light to heavy vehicles.

The following figure illustrate that whatever is the source of NG or biogas, it can be used either in a compressed form or a liquefied form. New industrial processes are combining the purification step with the liquefaction step in order to optimise the conversion of biogas into liquefied biomethane.

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**Figure 2: Value chain of the business model for LNG as a fuel development where GNVERT is acting**
Figure 3: Schematics of the flexible way of distributing NG as a fuel

As it is illustrated in the following Figure, the compressed form is very well adapted to urban and suburban transportation, whereas the LNG is dedicated to regional and long haul transportation. Indeed, the autonomy of vehicles is greater with LNG and close to diesel, which is coping the need of medium and long distance transportation.

Figure 4: Mobility area for NG as a fuel

Bio-methane

Bio-methane as a fuel either compressed or liquefied is the best solution to cope with the dilemma of GHG and local pollutants linked to the transport sector. Bio-methane as a fuel can cover the widest mobility range from urban transport to medium and long haul transport and from light vehicles to heavy vehicles with no CO₂ emissions.

The key parameters for the development of biomethane as a fuel are:

- Solely solution that can decrease CO2 emission from well to wheel by more than 90% for all kind of vehicles from cars to trucks.
- Very low local pollutant emission as NG.
• Local production decreasing energy dependency
• Circular economy from waste to fuel
• The best and more visible valuation of bio-methane
• The best bio-fuels because it can be produced from waste without spoiling agricultural human food.
• If dedicated agricultural solution is developed, the yield of energy per surface is the highest (2 to 4 times higher than other bio-fuels)
• High potential of production: biomass, algae, wood gasification…
• A product fully harmless and safe

**Truck’s Technology**

• Spark ignited
  Dedicated spark-ignited natural gas (SING) engines operate on the same principles as the common gasoline engine, the Otto cycle. Such engines are most commonly operated in a premixed mode with either lean burn or stoichiometric gas mixtures. Fuel (in this case natural gas) is drawn into the engine along with the intake air and ignited with a spark plug. The combustion process is characterized by premixed flame propagation typical for Otto (gasoline) engines.

  The largest SING engines currently have a displacement of approximately 9 L with an upper power level of 330 hp. A major advantage of these engines when run with stoichiometric air fuel ratios is the relatively simple aftertreatment system. Problems are poor part load efficiency and high requirements on the ignition system and that the upper engine load is limited by knocking. SING engines have gained significant acceptance in markets that place a premium on low emissions, where maximum efficiency is not a top concern, and whose power and torque requirements are modest for a given engine size. Strategies using cooled EGR have the potential to improve part load efficiency as well as increase the load range.

• Dual fuel
  For engine sizes in the 12-16 L displacement range (400-600 hp) alternative gas engine technologies are required. The main alternative heavy duty gas engine technologies can be identified as having potential for high efficiency and low emissions and is usually called “dual-fuel”. Two different solutions exist for dual fuel technology one being direct injection and the other one indirect injection.

  The Dual-fuel direct injection or called High Pressure Direct Injection (HPDI) technology retains the operating principles of the conventional base diesel engine direct injection near top-dead-centre, auto-ignition, diffusion combustion, and the thermodynamic Diesel cycle and so retains its operating characteristics. Gas is supplied using a special high pressure gas injection system. Pilot quantities of diesel fuel are injected into the cylinder in order to accomplish ignition. Major advantages of HPDI engines are that they match the parent diesel engine in power, torque, efficiency, and transient response, which no other gas engine can do. Such engines are not limited by knocking at high loads and their HC emissions are low. An HPDI engine is a Diesel-cycle engine that runs on natural gas, rather than being a conversion to the Otto cycle, which most other gas engine are.

  Dual-fuel indirect injection technology fumigates natural gas into the engine along with the intake air and ignites this with a small diesel pilot injection, so its operating principle is more like that of a conventional spark-ignited Otto-cycle engine. Gaseous fuel is injected in the inlet port of the engine and premixed with air/EGR during the intake and compression stroke. Ignition of the charge is managed by injection and auto ignition of a small amount diesel fuel using a conventional diesel injection system. The diesel ignition is advantageous, compared to spark ignition, by providing stable ignition also at high diesel like in-cylinder pressures and for conditions with lean air fuel ratios and/or high EGR. In addition, ignition takes place simultaneously in a large fraction of the cylinder volume leading to a heat release with shorter duration
compared to a situation where ignition is localized in a small volume surrounding the spark plug. Substitution rates of 50% to 75% can be achieved depending on several factors including duty cycle and the level of integration with the based diesel. Dual-fuel indirect injection engines can meet most of the technical requirements of modern diesel engines, although peak power, maximum torque, efficiency, and transient response suffer as substitution rates increase. The upper load range is typically limited by knocking, also giving a sensitivity to fuel quality. Overall, such dual-fuel indirect injection engines do not offer as large an improvement in emissions, fueling economics, and energy security as high pressure direct injection does. But by retaining the stock diesel fuel system, such engines can revert to 100% diesel operation at any time, which can be an advantage where natural gas refueling infrastructure is limited. However, operation on diesel-only erodes the business case to pay back the incremental vehicle cost based on fuel cost savings and drives the added complication of having emissions controls, such as aftertreatment, unique to each operating mode.

Infrastructure’s Technology

Below, the schematics of a LNG fueling station are presented. The LNG fueling station is equipped with a cryogenic dispenser for filling the LNG vehicles. The LNG fueling station is equipped with a cryogenic dispenser for filling the LNG vehicles.

![Figure 5: Schematics of an LNG fueling station](image)

The problematic of boil-off, storing the vapour phase under high pressure in gaseous form can be easily solved by adding a CNG filling line with an hydraulic pump and a CNG dispenser.

According to safety issues the location of filling stations should be far away enough from public buildings like schools or hospitals and living areas. The exact distances are fully described in French regulations and therefore risk scenarios are easily defined and accepted by local authorities.

The assessment of the accuracy of the risk scenarios was one objective of the trials achieved with truck manufacturers in order to the acceptance of the technology.

Today no standardisation of connectors at the dispensers and filling stations exists. Currently we have systems with one or two hoses, depending on the system pressure. The standardisation is already in progress. The goal must be to define a standard which combines safety issues, easy handling, cost efficiency and a minimum maintenance demand.

**Forecast development**

According Eurogas analysis, as it is indicated in the Figure hereafter, in 2050 NG and Biogas could represent more than 30% of final energy consumption for transport. LNG is the growth vector of NG as a fuel in the next decades and Biomethane has to be considered as a second shuffle of NG.
Figure 6: Forecast development of NG as a fuel in transport

The key parameters for the development of NG as a fuel and consequently LNG are:

- Price of competing fuels (oil, biofuels)
- Development of competitive technologies (such as plug-in hybrid electric vehicles, electric vehicles, biofuels, LPG, hydrogen)
- Political, economic and technical viability of the fuel compared to other vehicle/fuel CO2 mitigation options
- Environmental constraints
- Energy security (for gas producing countries in particular)
- Dilemma: investments in infrastructures or customer base first (B to C vs B to B)
- Level of Government and regulatory support and funding

4. RESULTS

IVECO

In November 2011, GNVERT with IVECO decided to perform the first LNG as a fuel trial in France with a 44t trucks. The duration of the trial was 4 weeks.

For the trial IVECO provided a truck IVECO Stralis 330cv. The truck is 330 horsepower and it is spark ignited with a stoichiometric gas mixture. On the side of the truck were located 2 storages of NG. The main storage is for LNG and the emergency storage is for CNG (Compressed Natural Gas)

GNVERT provided the LNG infrastructure of distribution. The LNG is provided thanks to a mobile device that is filling directly the truck thanks to a cryogenic pump. Specific cryogenic hoses are connected on the cryogenic tank of the truck. A well trained operator is manually cooling down the system and ensuring the smoothness of the LNG flow to the tank of the truck. A mass flow meter was specifically installed in order to measure precisely the exact amount of LNG that was loaded into the trucks.

In order to achieve a very low level of GHG emissions, liquefied biomethane was used for the trial.

The trial was performed under real conditions with a transport company customer called “Transport P.MENDY”. The trucks was firstly used on regional transport for the retail of supermarket and secondly on long distance transport.
During the first part of the trial that lasted 2 weeks, the truck was running night and day and travelling 400km per day with a relatively medium load on the portage of the truck. For the second part of the trial that lasted 2 weeks, the truck was running at full load on highway and travelled 1000km per day.

During the trial several parameters either quantitative or qualitative were monitored:

- The consumption of the truck according to the load and the profile of the road (flat or sharp)
- Noise and perception of the drivers
- The comfort of driving
- Engine break
- Acceleration
- Acceleration at low speed and low torque
- Gear box

According IVECO, the expected consumption of the truck is 35kg/100km. The measurement of the consumption was lower and in average close to 27-28kg/100km. But the consumption varied significantly with the profile of the road. In a hills area the consumption reached 35kg/100km. A second parameter that has an incidence on the consumption was the behaviour of the driver. Finally, the load of the truck has also an influence on the consumption. The figure hereafter is indicated how was varying the consumption profile according to the load of the truck.

![Figure 7: Consumption profile according the load of the truck](image)

Qualitative parameters were marked by the 4 drivers that have participated to the trial. All drivers gave a note for each parameter according a reference that is a diesel engine truck of the same category.
Figure 8: Qualitative parameters quotation results

- **Noise**: the truck is very quite with almost no vibration whatever the speed is. Time to time when stopped, drivers opened the window to hear if the engine was still running! At very high engine speed, often used at full load while climbing a sloppy road, the noise was comparable to the one of diesel with less vibration.

- **Acceleration**: the feeling of acceleration was more important mainly due to the fact that it was recommended to run the truck at high engine speed.

- **Driving comfort**: Drivers appreciated the lack of noise and vibration. The drive of the truck was perceived as softer than the one with a diesel engine.

- **Engine break**: the engine break is much less efficient than the one of a diesel engine.

- **Gear box**: the use of a gear box was very well accepted.

Pictures hereafter are illustrating the LNG tank of the truck and the fueling of the truck thanks to the mobile LNG station provided by GNVERT.
In September 2012, GNVERT with VOLVO decided to perform a LNG as a fuel trial in France with a 44t trucks. The duration of the trial was 4 weeks.

For the trial VOLVO provided a truck on a based of a 13L diesel engine converted with a dual fuel kit provided by “Clean Air Power”. The truck is 460 horsepower and it is dual fuel with a gas ratio close to 75%. On one side of the truck was located the storage of LNG and on the other side was located the storage of diesel. The storage of LNG is design for an autonomy of 500km.

GNVERT provided the LNG infrastructure of distribution. The LNG is transfered by a mobile device that is filling the truck thanks to pressure differential and an automatic dispenser. Specific cryogenic hoses are connected on the cryogenic tank of the truck. All drivers were trained to ensure the filling of the truck thanks to an automatic system. A mass flow meter located in the dispenser gives precisely the exact amount of LNG that was loaded into the trucks.

The LNG was coming from Barcelona terminal with a methane index higher than 85. This point was mandatory for Volvo in order to avoid any knocking effect in the engine that could damage the injection system.

The trial was performed under real conditions with a transport companies firstly in the south west of France and afterwards in Paris.

During the trial that lasted 4 weeks, the truck was running daily with an average of 600km per day with a load that was varying from 16 to 24 tonnes.

Pictures hereafter are illustrating the fueling of the truck thanks to the mobile LNG station provided by GNVERT and the mobile filling station with the dispenser used by GNVERT.
CNG/LNG 1st French Fueling Station at Gennevilliers:

The First LNG Station in France is built in Gennevilliers, part of the European “Blue Corridor program, in the vicinity of the inland harbor of Paris.

The station is also delivering CNG as fuel. It has 2 compressors of 470Nm3/h each and 2 dispensers. About 60 people are using every day this CNG station.

In January 2013, the 20m3 tank and pump skid iso-containers was assembled in Gennevilliers. The solution was originally designed by CRYOSTAR. But, as the tank from CHART was a standard mobile tank, additional safety improvements have been decided by GNVERT (additional gas sensor, automatic valves). Other technical and critical improvements have been performed with the contribution of both supplier engineering departments, especially for the regulation compliance.

A fuel management system is connected to both fuel, the user can choose their appropriate fuel, LNG or CNG.

If needed, this LNG station could easily be dismantled and installed in other place as it is transportable. In the next future, the boil off will be connected to the inlet pipe of the CNG Station and then it could be fully used as an L-CNG station.

CNG and LNG French safety regulations have been considered in the layout of the installation. All failures are connected and monitored to both station. An emergency default will stop all activities (such as closing all valves, switching off electricity). In case of fire, closed to the LNG dispenser, the automatic extinguishing will spray the 50kg powder to cover the fire. As well, for operating uses, the station has a real-time web based system monitoring and is under video surveillance.
LNG European Blue Corridors

A first definition of European LNG Blue corridors, with 4 different corridors, is covered in the present project. This comprises the definition and detailing of the four transport corridors in number and capacity of refueling stations, connection to terminals and traffic density in terms of geographic location and in time.

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Acronym</th>
<th>Description transport connection</th>
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<tbody>
<tr>
<td>Atlantic</td>
<td>ATL-BLUE</td>
<td>London, Rotterdam, Antwerp, Paris, Bordeaux, Bilbao, Barcelona, Madrid and Lisbon</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>MED-BLUE</td>
<td>Lisbon, Madrid, Barcelona, Montpellier, Marseille, Nice, Torino, Milan, ….</td>
</tr>
<tr>
<td>South to North</td>
<td>SONOR-BLUE</td>
<td>Lisbon, Madrid, Barcelona, Montpellier, Marseille, Lyon, Dyon, Strasbourg, Frankfurt, Ruhr area, Hamburg, Kiel, Copenhagen, Malmo, Oslo, Stockholm</td>
</tr>
<tr>
<td>West to East</td>
<td>WE-BLUE</td>
<td>London, Paris, Frankfurt, Prague, Vienna…</td>
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The outline of the roll out of the first stage of the roadmap is to build approximately 15 LNG or L-CNG stations on critical points/locations in the Blue Corridors and to build up a fleet of approximately 100 LNG Heavy Duty Vehicles and/or DF vehicles.

A set of LNG fuel stations, both fixed and mobile, will be used for the first demonstration of the European LNG Blue Corridors. The LNG fuel distribution between the main fuel stations will be performed via LNG road tankers (mobile filling stations). The use of mobile stations provides flexibility to fuel those vehicles which run on routes where not fix stations are available as well as during the period of time necessary to understand the best location and fueling station capabilities for the fix one.

The overall objective of LNG Blue Corridors is to perform a large-scale demonstration in order to facilitate a broad market development for heavy duty vehicles running with liquefied methane.

Specific objectives for the project are:

- To optimise the complete powertrain and storage system of LNG heavy duty vehicles with respect to energy efficiency and pollutant emission, by fully utilising the technical potential of liquefied methane in an optimised fuel-engine system. The project should take into account the work of complementing projects such as GREEN, INGAS and any other developing similar technologies and should address all the key components of LNG powertrain including:
  - High performance heavy duty natural gas engine including injection systems, aiming at efficiency close to that of current diesel engines.
  - Low temperature after-treatment systems for heavy duty natural gas engines, to abate in particular NOx and unburned methane emissions, to comply with post-Euro VI requirements.
  - Liquefied natural gas tank systems including boil-off treatment or high volumetric efficiency solid state compressed natural gas storage systems.

- To analyse data from current pre-commercial demonstrations, and to perform additional demonstrations in different environments, in order to facilitate a market development for heavy duty vehicles running medium and long distances with LNG.
• To carry out benchmarking and assessment of the different vehicles technologies, where needed by coordinating with existing projects at EU and national level, including full safety assessment.

• To evaluate energy efficiency, costs, performance, environmental benefits and durability of heavy duty vehicles running on LNG under different climatic, geographic and traffic conditions.

• To provide recommendations for the development of relevant standards, in particular for the homologation of LNG heavy duty vehicles and refueling stations.

• To demonstrate a LNG distribution system by road tankers as a means of distribution of LNG to refueling stations available in different parts of Europe.

• To provide recommendations for cost-efficient and safe distribution network and refueling stations for liquefied methane.

The consortium is composed of 29 members that are representative stakeholders of the business: OEM's, gas companies, equipment suppliers…

The duration of the demonstration is 4 years with a kick off early in 2013. All members of the consortium are going to collaborate in 8 working packages in order to fulfil all the objectives listed above.

4. CONCLUSIONS

Natural gas is a flexible fuel that is used extensively in power generation and competes increasingly in most end-use sectors. It offers environmental benefits when compared to other fuels. Gas resources are abundant and therefore new gas territories are investigated. LNG as a fuel is an important market segment from the fact it can provide solutions for any type of mobility: road, rail and maritime.

GNVERT, subsidiary of GDF SUEZ and the main player in the Natural Gas Vehicles (NGV) fuel sector in France, investigate LNG as a fuel since 2010. The development of LNG as a fuel for the road transport was achieve thanks to a close collaboration and partnership between several stakeholders and more specifically truck manufacturers.

After 2 successful trials, one with IVECO and the second with VOLVO, GNVERT decided to built, end 2012-beginning 2013, the first LNG fueling station in France. Furthermore GNVERT is ensuring the development of this new segment by participating at several demonstrations and projects at the European level.