

The use of Natural Gas in the transportation Industry

European LNG Blue Corridors

EAGN 2012. The Golden Age of Gas
AGN Annual Meeting
Lisbon, October 2nd, 2012

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General Manager

Advantages of bio natural gas

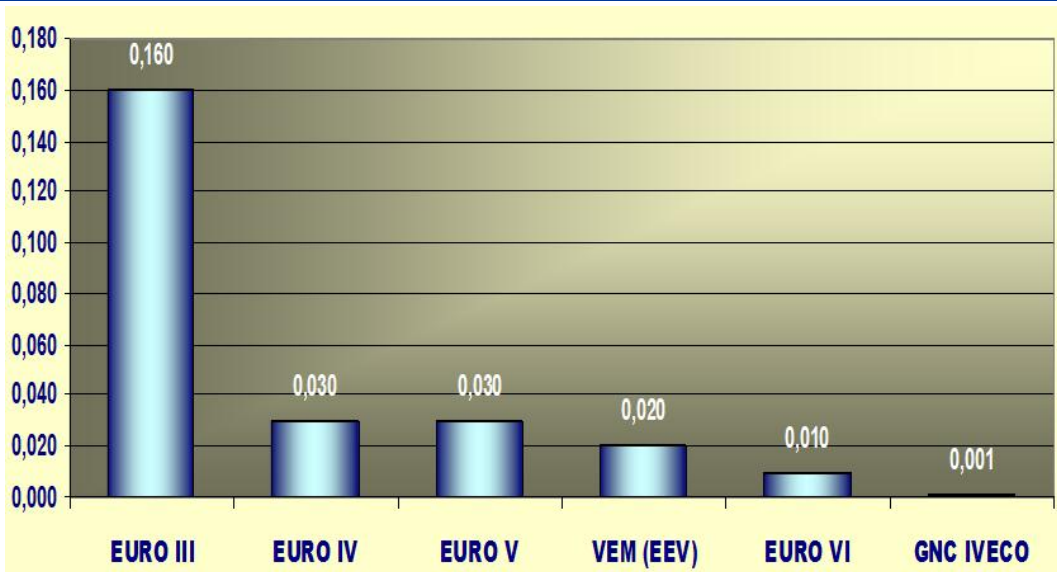
- Natural gas is an alternative fuel coming from natural wells. It is mainly methane (CH_4)
- Biogas is also a methane rich gas, produced by the fermentation of the biomass, it is then a renewable fuel.
- **Methane contents 25% H and 75% C, in weight**

As a comparison,

- Petrol contents 13,5% H and 86,5% C
- Diesel oil contents 13,5% H and 86,5% C
- LPG contents 17,4% H and 82,6% C

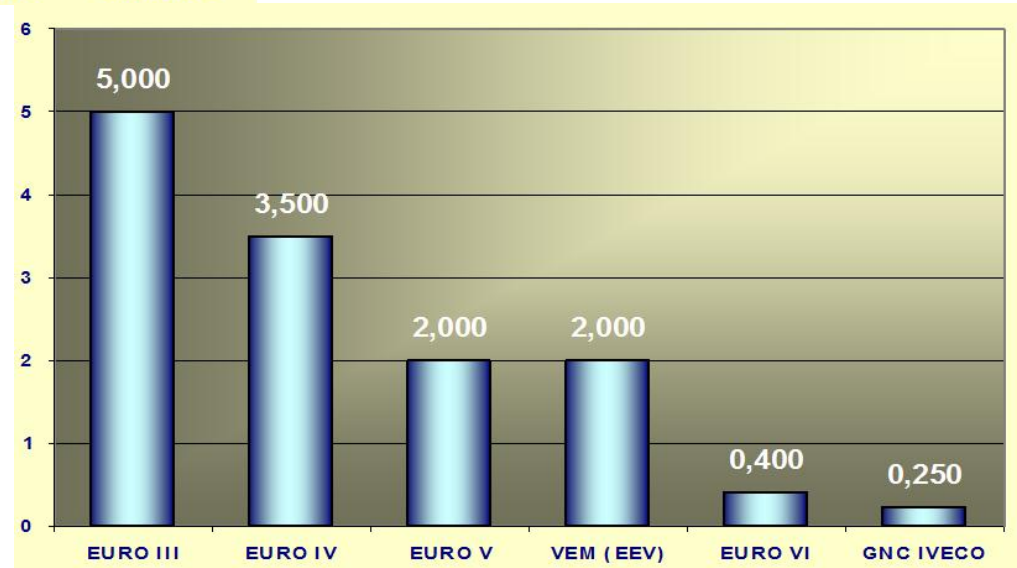
Due to its molecular advantage, regulated exhaust emissions and CO_2 are particularly favourable in the engines running on natural gas.

Exhaust pollutants limits



PM limits

NOx limits NO₂ is not measured

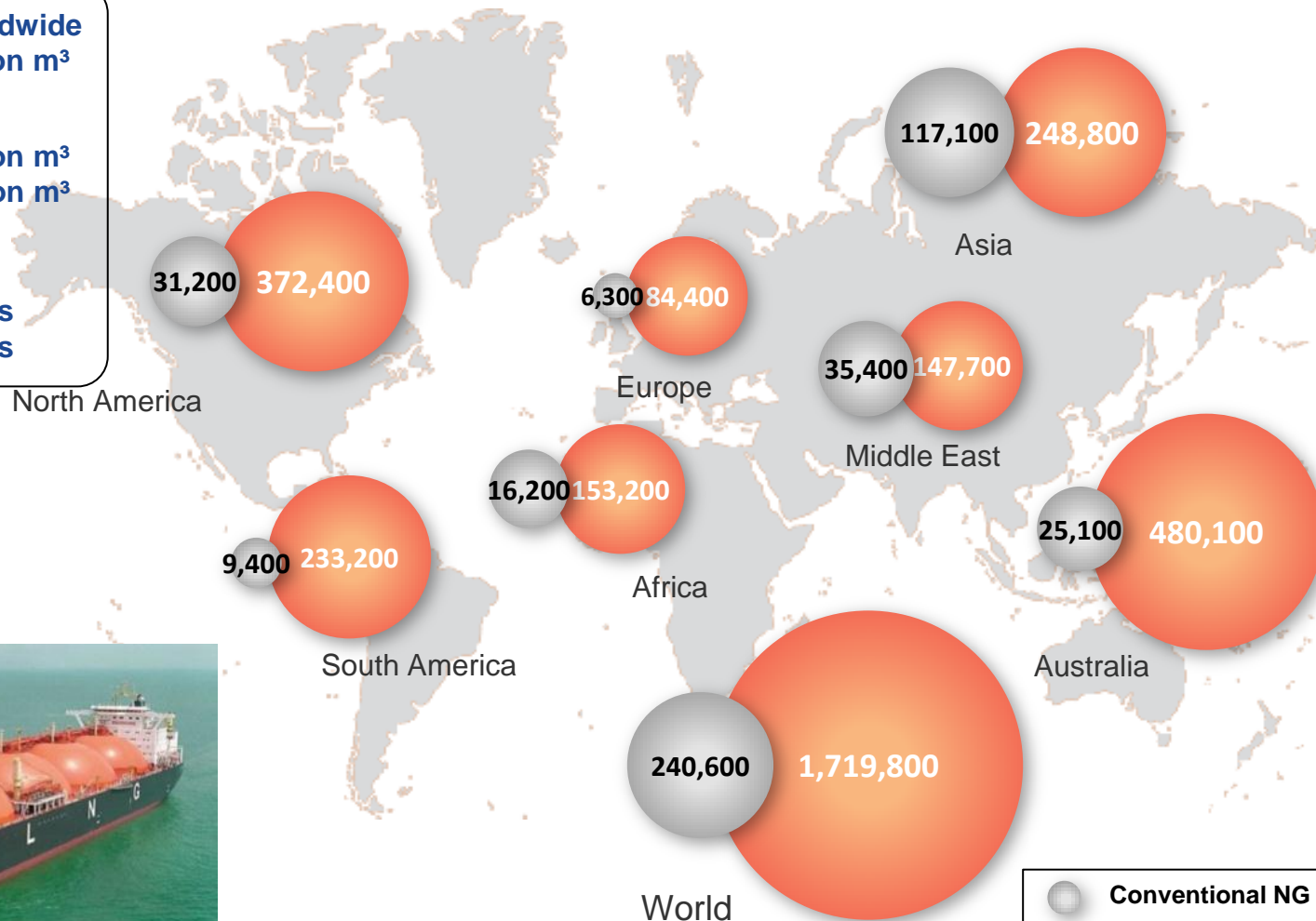


Worldwide gas reserves (unit= 10^9 m^3)

Gas consumption worldwide (2010): 3.200 billion m^3

Europe:
Total 522 billion m^3
NGVs 1,8 billion m^3

Reserves:
World: 537 years
Europe: 161 years

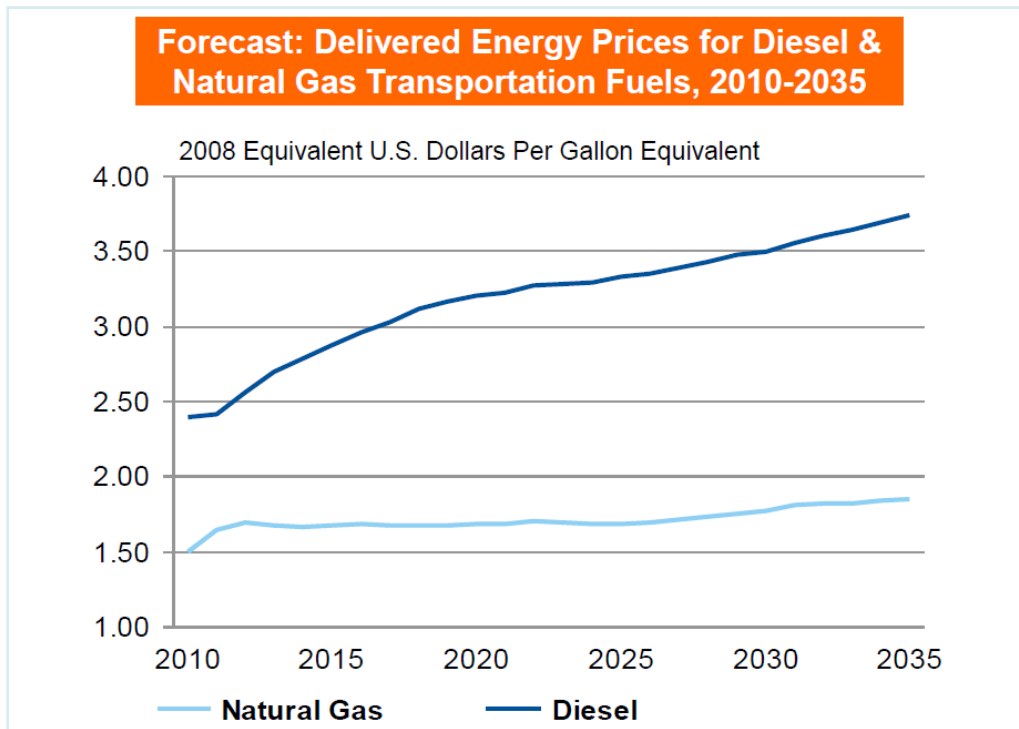


Source: data BGR, graph works NGVA Europe

US, unconventional (shale) LNG exporter

Gas Natural firma un contrato para abastecerse en EE UU por 20 años

Cheniere suministrará cada año el equivalente al 15% del consumo de España
El País, 23rd November 2011



Source: U.S. Energy Information Administration,
Annual Energy Outlook 2010

In 2008, non conventional gas meant 8% of the total US gas consumption.

In 2035 EIA estimates unconventional gas could reach 57%!

US EIA forecasts prices for diesel and gas will continue being decoupled.

The world NGV champions

Total NGV in the world: 13.2 million

PAKISTAN (in 10 years)

Total CNG vehicles:

3,500,000 i.e. ~ 80 % of the running park.

Refuelling stations: 3,300

IRAN (in 5 years)

Total CNG vehicles: 2,070,000

i.e. ~ 13.0 % of the running park.

Refuelling stations: 1,540

ARGENTINA

Total CNG vehicles: 1,900,000

i.e. ~ 23.0 % of the running park.

Refuelling stations: 1,880



BRAZIL

Total CNG vehicles:

1,640,000 i.e. ~ 5.0 % of the running park.

Refuelling stations: 1,780

INDIA

Total CNG vehicles: 1,100,000

i.e. ~ 8.0 % of the running park.

Refuelling stations: 600

ITALY

Total CNG vehicles: 740,000

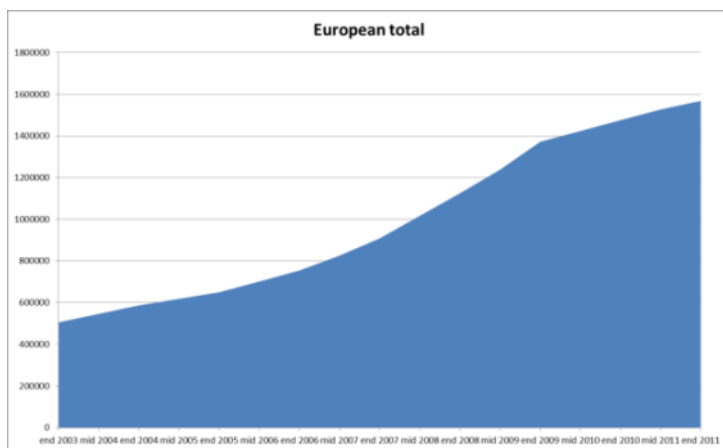
i.e. ~ 2.0 % of the running park.

Public refuelling stations:
>850 (as of June 2011)

Source: The GVR – Gas Vehicles Report (February 2011)

NGVs in the world

1991 to 2020 growth and forecast



Europe:
16% growth (2006-2011)

World:
70+ M NGVs in 2020!

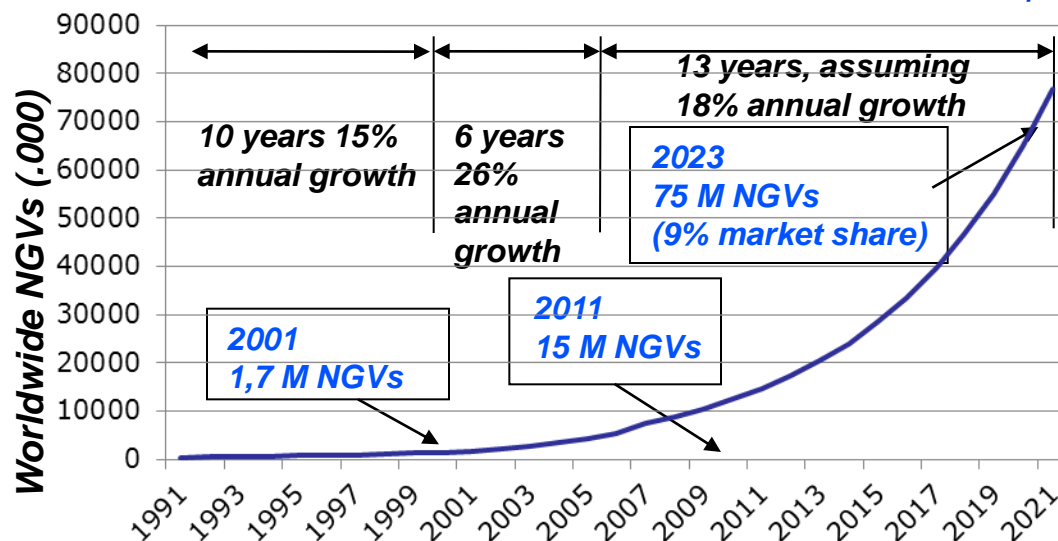
Source: NGVA Europe

Global market for NG trucks is expected to grow at a Compound Annual Growth Rate of 14% between 2012 and 2019, while NG buses are expected to grow at 19% during the same period.

This growth is being fueled by:

- economic growth following the global slowdown of the last few years
- increased vehicle availability
- environmental benefits
- and the desire for increased energy security.

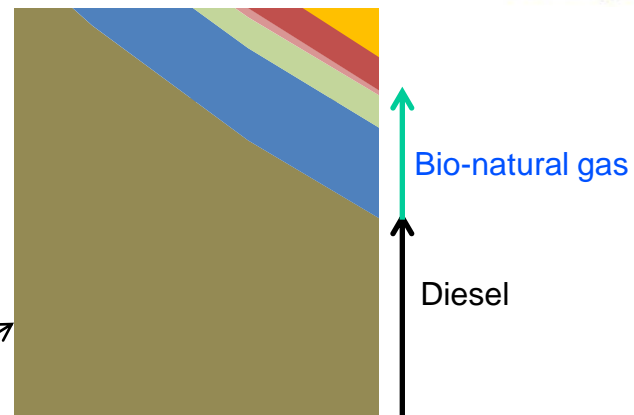
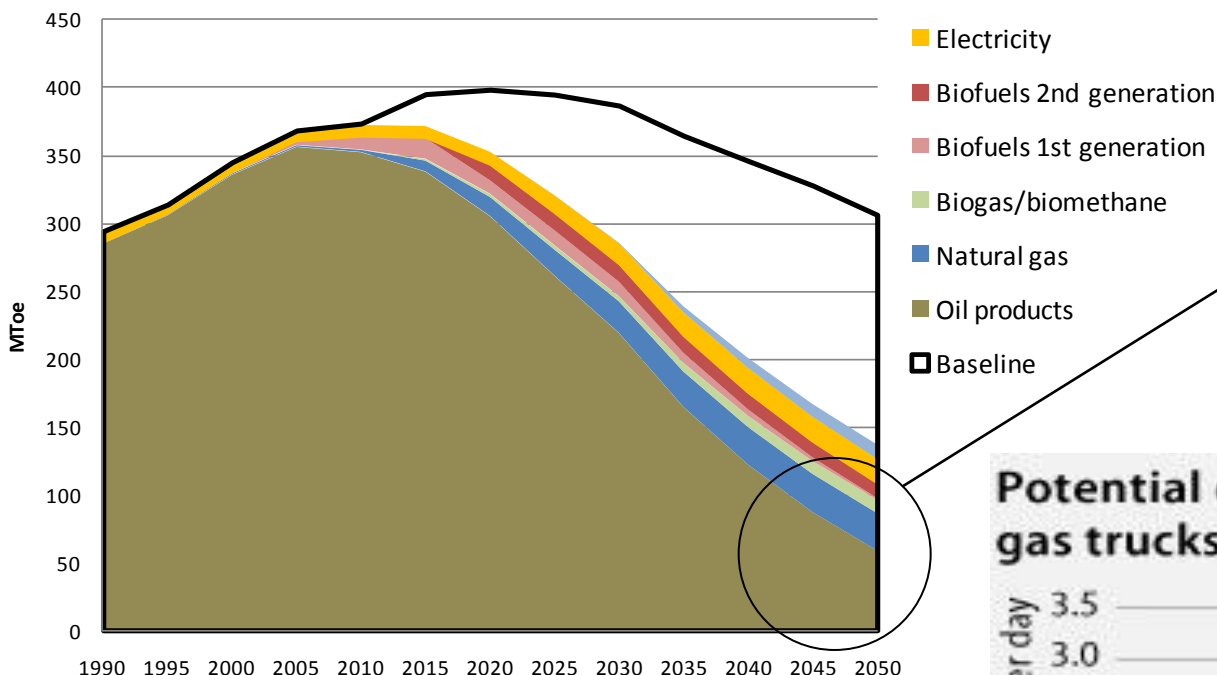
Pike Research, September 2012



Eurogas Roadmap 2050 (10/2011)

Expected market share: 9% in passenger, 33% freight

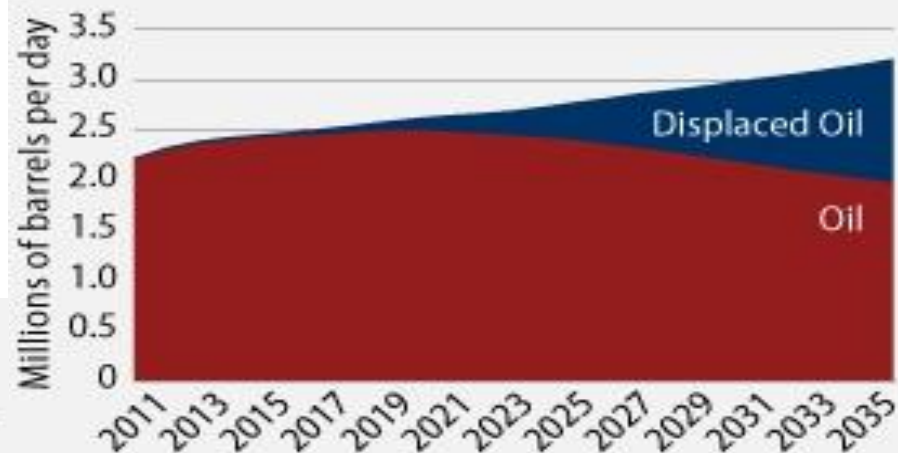
Final energy consumption - Transport



North American forecast: 37%

Sources: Energy Information Administration, Annual Energy Outlook 2010, Supplementary Tables 46 and 67, available at: http://www.eia.doe.gov/oiaf/aeo/supplement/sup_tran.xls#set3.1118a!C170 and http://www.eia.doe.gov/oiaf/aeo/supplement/sup_tran.xls#set3.1118a!C2275

Potential oil displacement from natural gas trucks and buses



CNG urban trucks and buses in Europe

70.000 urban buses give service in the main European cities (Italy, France, Germany, Spain, Sweden, Greece, Portugal, Netherlands)

9.000 (13%) are CNG.

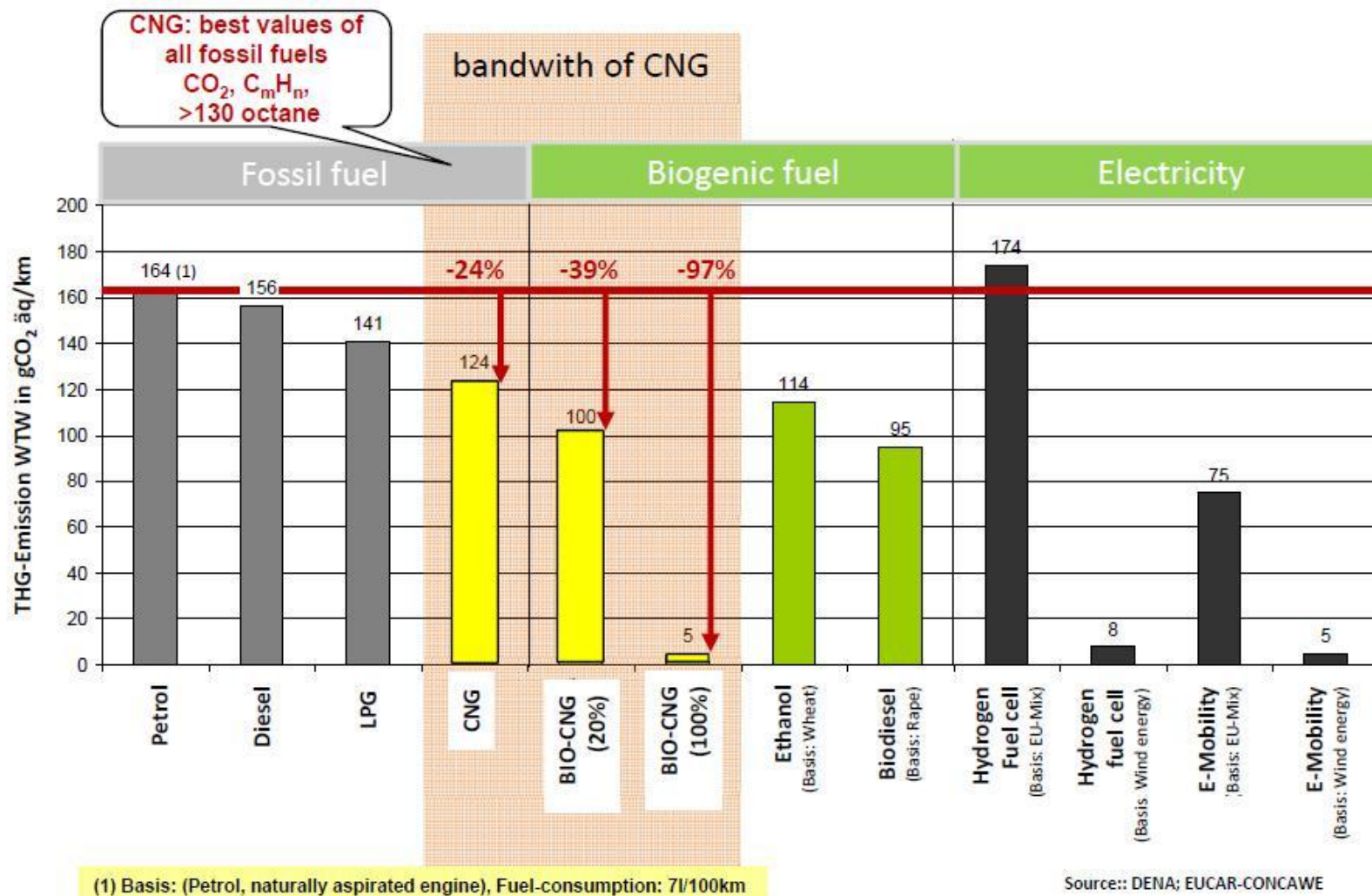
20.000 garbage trucks in service in Europe (France, Spain, Italy, Greece)

3.000 (15 %) are CNG.

On top of the great advantages in exhaust emissions, Natural Gas vehicles offer a very silent operation, much appreciated in urban centres.



Well-to-Wheel balance of vehicle fuels



Source: German Energy Agency (DENA) Study 2010

Strong municipal decisions on alternative fuels

In February 2010 EMT (*Empresa Municipal de Transportes, Madrid*) declared its intention to stop buying diesel buses.

Purchases done in 2010 for deliveries in 2011, 2012 and 2013 are all CNG, except for some special units not yet available with CNG engine.

EMT is the third largest bus company in Europe, with more than 2.000 units in service.

Its CNG fleet composition is:

2011: 430 CNG buses (27 %)

2012: 700 CNG buses (35 %)

Medium term: 1.000 CNG buses (50 %)

Barcelona's TMB (1.000 buses) is following the same scheme of CNG share in its fleet.

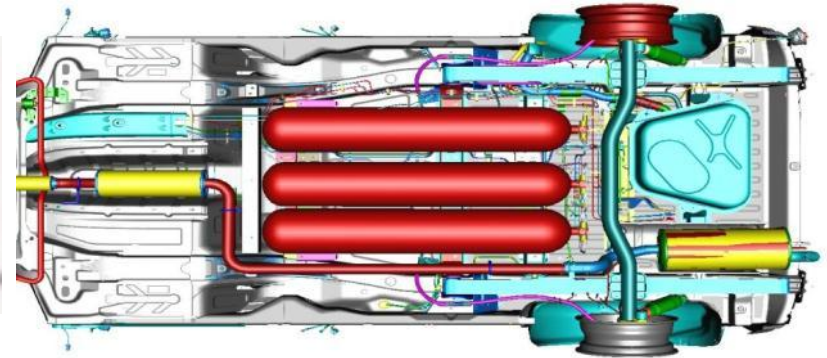


New EMT bus depot in Madrid

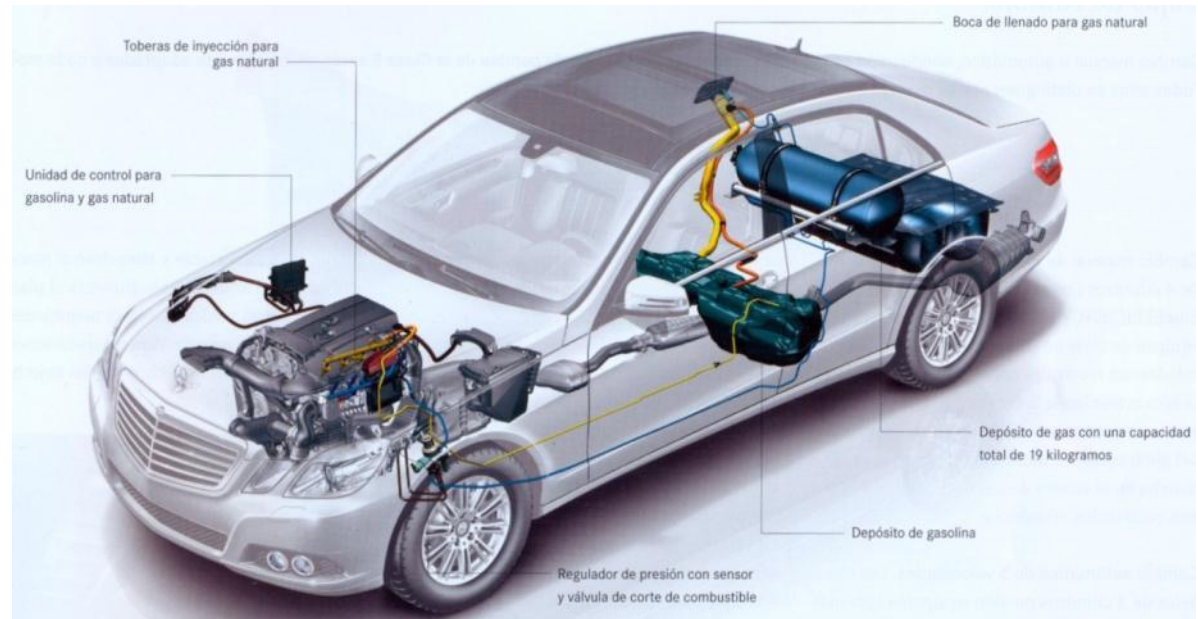
Design capacity: 400 CNG buses
CNG tank capacity per vehicle: 150 kg
Maximum allowable time for refuelling:
3 minutes.

The filling station building has an external access for other customers.

Underfloor tanks save space



Modern cars have CNG tanks installed underneath the floor, offering the same internal space for passengers and luggage than the petrol or diesel equivalents.



Biogas (also LBG) production potential



Kilometers driven by hectare used

Bioethanol
2.500 Litre

Biodiesel
1.550 Litre

Rape-Oil
1.480 Litre

Biomethane
3.560 kg



Source: Fachagentur Nachwachsende Rohstoffe

Among different options of biofuels, biomethane presents the highest efficiency per hectare of land.

A global European estimation shows a potential of:

2.750 TWh (9,9 EJ=238 Mtoe),
made out of:

1.500 TWh (5,4 EJ=130 Mtoe)
coming from crops, plus another
1.250TWh (4,5 EJ=1.108 Mtoe)
coming from other sources: sewage,
manure, landfills, etc.

If we choose bioethanol instead of biogas we would lose the potential of the waste, sewage, etc (1.250TWh, 4,5EJ=108Mtoe) and we would also reduce the efficiency of the land by 47%.

In other words we would obtain:

800TWh (2,9 EJ=70 Mtoe) instead of 2.750TWh (9,9 EJ=238 Mtoe).

Biogas is the perfect fuel for food distribution and other urban activities



Deliveries of Coca Cola UK in London for the Olympic Games will be done exclusively with CBG trucks.

Some garbage collection companies in Switzerland are also using biogas.



CBG buses in Nijmegen (NL)



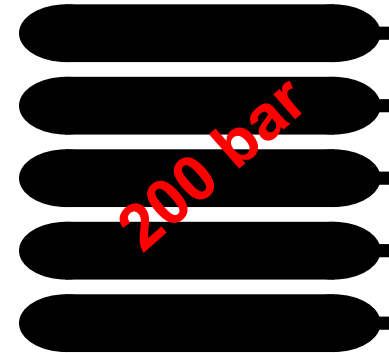
CNG Net, a subsidiary of the NGVA Europe member Ballast Nedam, is set to deliver 12 million m³ of biomethane for all 225 city buses of Connexxion in the city area of Arnhem/Nijmegen in the Netherlands, from the end of 2012. This will be the largest public transport concession for biomethane in the Netherlands and unique in Europe.

LNG trucks for long distance transport



Diesel vs CNG & LNG.
Autonomy equivalence

1 liter Diesel oil



CNG
5 litre

-162°C at 1 bar
-125°C at 10 bar

LNG/LBG
1,8 litre



Two engine technologies are available for heavy engines:

- Dedicated, using 100% natural gas
- Dual fuel, using diesel injection for ignition and natural gas as the main fuel

LNG opened the way for the medium and long distance road transport

LNG truck refueling process

Standardization needed!



Single hose filling,
low working pressure, 7-10 bar (**Chart**)



Double hose for filling and venting,
high working pressure, 18 bar (**Indox**)
(MB to adopt to 7-10 bar shortly)

European LNG heavy duty tractors



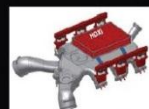
European LNG park:

200 LNG vehicles

25 filling stations (end 2012)



Soluciones en Gas Natural en Camiones: Tecnología dual-fuel



- Acuerdo de colaboración con Hardstaff para dualización de Actros/Axor
- Homologación en España en proceso
- 150 unidades en funcionamiento dualizadas
- Funcionamiento con GNC/GNL
- Sustitución 40-70%
- Ahorro hasta 25% del coste de combustible

North American and Australian LNG trucks



**Autocar
International
Freightliner
Peterbilt
White**

...

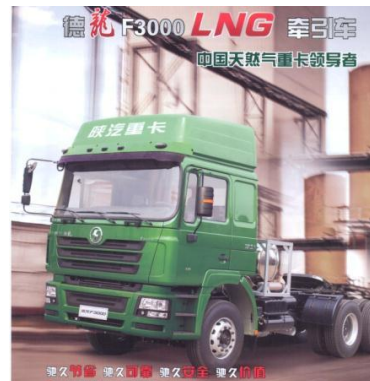


More than 6.000 LNG heavy trucks already running in USA!

Chinese NG trucks



Foton
Sinotruk



Shaanxi



Dong Feng



Today: 12.000 LNG heavy trucks & buses in service and 300 LNG fuel stations!
2015 (5-year-plan target): 200.000 LNG vehicles and 1.500 fuel stations!!

Cost difference between a Diesel and a LNG powertrain (including aftertreatment) will be dramatically reduced in Euro VI.

Reference:

«TNO report 06.OR.PT.023.2/NG. Euro VI technologies and costs for Heavy Duty Vehicles»

Forecasted cost increase from Euro IV to Euro VI. Emissions scenario n° 5

Diesel engine:	+ 13.486 €	} Delta cost reduced in 11.660 € !!
Stoichiometric NG engine:	+ 1.825 €	
Lean-burn NG engine:	+ 4.025 €	

Types of vehicles and alternative fuels

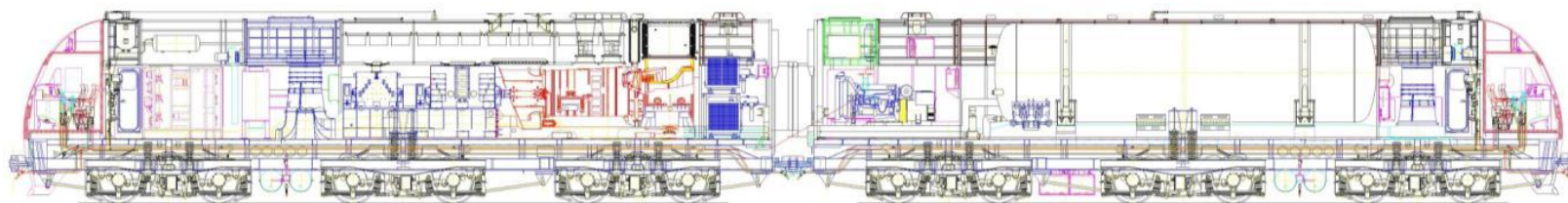
Vehicle type	Present fuel	LPG	Liquid biofuels	Full electric	Hybrids (energy recuperation)	Bio-natural gas (CNG & LNG)
Three wheelers	Petrol	Yes (mostly converted)	Yes (%)	No	No	Yes (CNG)
Cars	Petrol & diesel	Yes (mostly converted)	Yes (%)	Yes (city cars)	Yes	Yes (CNG)
Vans & delivery trucks	Diesel	Yes (vans), mostly converted	Yes (%)	Yes (city use only)	Yes	Yes (CNG)
Heavy urban trucks	Diesel	No	Yes (%)	No	Yes	Yes (CNG)
Suburban & urban buses	Diesel	No	Yes (%)	Yes, small Yes (wired)	Yes	Yes (CNG/LNG)
Coaches	Diesel	No	Yes (%)	No	No	Yes (LNG)
Heavy on road trucks	Diesel	No	Yes (%)	No	No	Yes (LNG)
Heavy off road trucks	Diesel	No	Yes (%)	No	No	Yes (CNG/LNG)
Railway locomotives	Diesel & electric	No	Yes (%)	Yes (wired)	No	Yes (LNG)
Ships	Diesel	Short sea (converted)	Yes (%)	No	No	Yes (LNG)
Aircraft	Diesel Jet A-1	No	Yes (%)	No	No	Yes (LNG)

LNG in railways



Russian locomotive with 8.300 kW gas turbine engine running on LNG.

In daily service since 2009.



LNG trains are also in service in Sweden, USA, Peru and other countries
Spain is considering the use of LNG to replace diesel in narrow track lines

LNG fuelled ships are growing rapidly



Nov. 1st, 2011. Japan's Ministry of Land, Infrastructure, Transport and Tourism had indicated its intention to develop safety standards for vessels powered by **liquefied natural gas (LNG)** which it expects will **largely supersede oil-fueled marine transportation**, reports L-News.

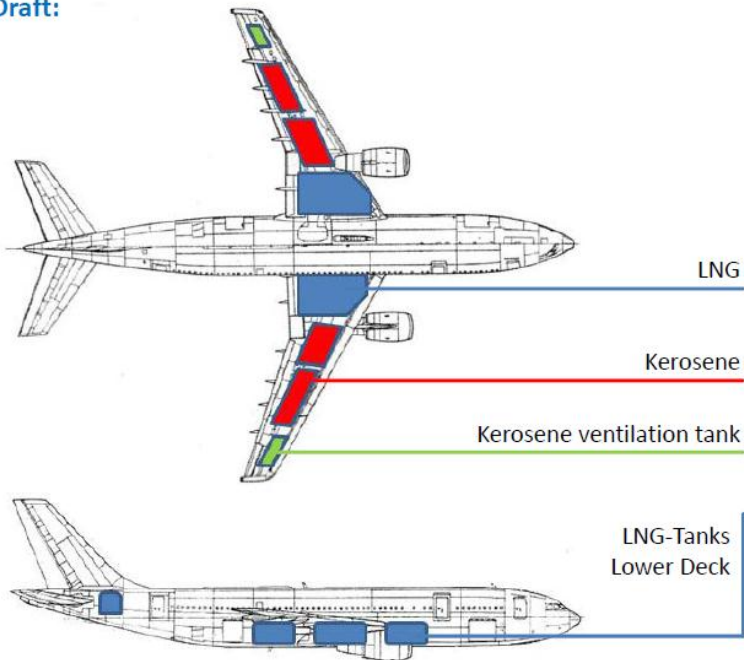
JPY 647 M (€ 6,2 M) has been set aside in the 2012 budget for **the creation of comprehensive safety measures pertaining to marine renewable energy**.

November 29, 2011 | Norway: **"We believe 500 LNG fuelled ships will be on order by 2015, several thousands by 2020,"** Mr. Remi Eriksen, COO of Det Norske Veritas Asia Pacific & Middle East

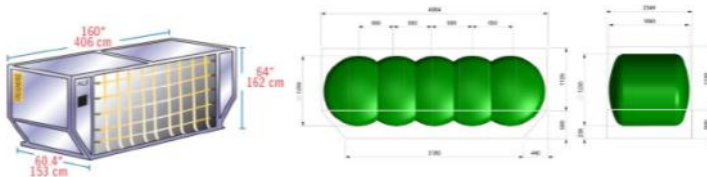
LNG in aircraft

Technical Concept of Container Tanks for Passenger & Cargo Flights **AIRLNG**

Draft:

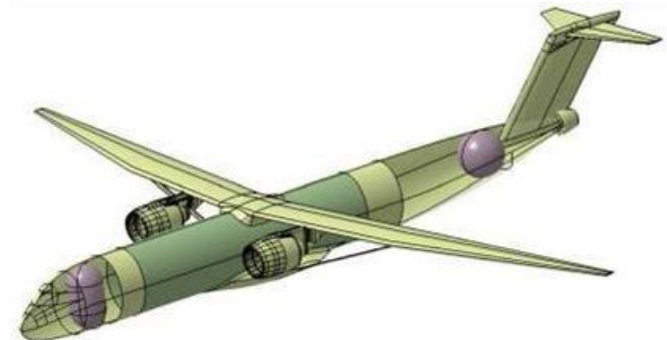


Multi-Lobe Tank Draft with LD6 container size:

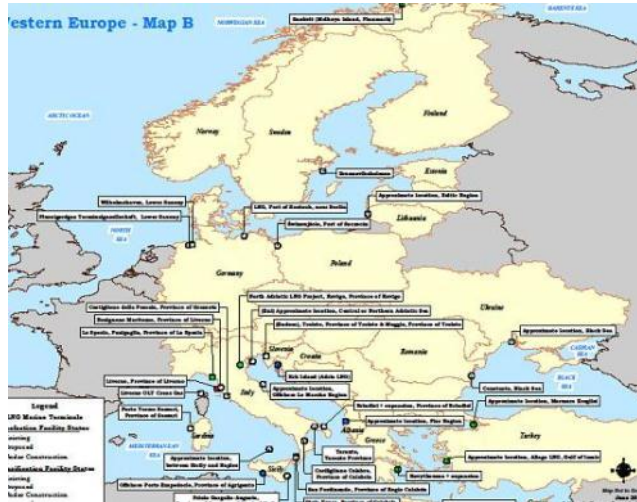


Boeing's proposal is an efficient airliner design, LNG fuelled, the company submitted to NASA in 2010 as part of the **Subsonic Ultra Green Aircraft Research project** (SUGAR Freeze).

The company says it could reduce fuel burn by 60 percent compared to a typical 737-800 used today.



LNG Terminals in Europe and in the world



LNG terminals in Western Europe

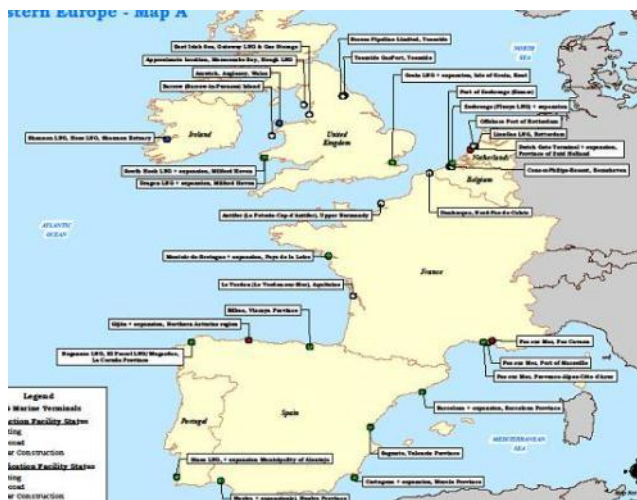
Liquefaction: 1 in Norway, above the Arctic Circle

Finland is also building a liquefaction terminal to store the imported Russian gas, not consumed (Take or Pay)

Regasification:

16 in operation (Portugal, Spain, France, Belgium, Italy, United Kingdom, Greece, Turkey)

52 projects (Albania, Croatia, Cyprus, Germany, Ireland, Netherlands, Poland, Romania, Ukraine)



LNG terminals in the world:

Liquefaction: 21 in operation
47 planned/being built

US is also building some liquefaction plants to export its new resources of unconventional gas (shale gas)

Regasification: 62 in operation
127 planned/being built

The LNG Blue Corridors Project



These initially proposed Blue Corridors will also develop with connection to other LNG distribution initiatives as:

- Danube Inland Waters Blue Corridor, from Romania to Viena
- AGRI (Azerbaijan-Georgia-Romania-Interconnection) project to transport LNG from Azerbaijan to the EU through Georgia and Romania.

NGVA Europe is working in the preparation of a European Program to develop the concept of **European LNG Blue Corridors**

The intention is to define four initial pan European routes with strategically placed LNG filling stations that would allow the heavy, long distance truck transport throughout Europe:

- Portugal-Spain to France, Netherlands, UK and Ireland
- Portugal-Spain to France, Germany, Denmark, Sweden
- Mediterranean arch to Italy and with another branch to Croatia
- Ireland-UK to Austria

GC.SST.2012.2-3. Demonstration of heavy duty vehicles running with liquefied methane

Call: FP7-TRANSPORT-2012-MOVE-1

Content and scope:

- The overall objective is to perform **large-scale demonstration** in order to facilitate a broad market development for heavy duty trucks running with liquefied methane. The specific objectives for the project should be:
 - To **optimize the complete powertrain and storage system of LNG heavy duty vehicles** with respect to energy efficiency and pollutant emission, by fully utilizing the technical potential of liquefied methane in an optimized fuel-engine system.

LNG demonstration project (2)

- **Implementation and management:**
 - The project should involve **cooperation between heavy duty vehicles manufacturers, fuel suppliers, fuel distributors and fleet operators, including trucks and buses.**
 - The heavy duty vehicles demonstration should be carried out in **at least three Member States**, and should be complementary to existing demonstrations running at national level.
 - The project should include a **first definition of European LNG Blue Corridors**, with strategic LNG refuelling points which would help to guarantee LNG availability for road transport in a simple and cost effective way.
 - The demonstration part of the project should help **to improve the knowledge and general awareness of LNG as alternative** fuel for medium and long distance road transport.
 - The project should also serve to **remove the existing barriers for heavy duty vehicles running on LNG.**
- **Expected impact:**
 - **Oil substitution** through the use of alternative fuels, namely liquefied methane (LNG).
 - **Reduction of GHG emission** from transport using liquefied methane as fuel in heavy – duty vehicles.
 - **Market development** for heavy duty vehicles running with liquefied methane.
 - **Increase of energy efficiency of heavy duty natural gas engines** to the level of the current diesel heavy duty vehicle engines.
 - **Achievement of EURO VI standard** for LNG heavy duty vehicles.

Existing and proposed LNG filling stations (March 2012)



▼ Existing LNG stations:

Spain: Abrera (Barcelona), Olaberria (Guipúzcoa), Lleida, Castellón, Guadalajara, Guadalajara (2012), Madrid, Zaragoza (2012), La Jonquera (Girona, 2012), Tarragona, Valencia (2012).

Portugal: Mirandela, Maia (2012)

Italy: Poirino (Torino)

Holland: Oss

Sweden: Göteborg, Järna, Malmö (2012), Jönköping (2012)

▽ Proposed:

Lisbon (Portugal)
Sines (Portugal)
Irún (Guipúzcoa), Spain
Lyon (France)
Paris (France)
La Crèche (France)
Metz (France)
Antwerpen (Belgium)
Ventimiglia (Italy)
Piacenza (Italy)
Palmanova (Italy)
Roma (Italy)
Karlsruhe (Germany)
Berlin/Postdam (Germany)
Hannover (Germany)
Munich (Germany)
Split (Croatia)
Örebro (Sweden)
Sundsvall (Sweden)
London Orbital M25 (UK)
South Wales M4 (UK)
Manchester M6 (UK)
Watford Gap (UK)
Dublin (Ireland)

Existing LNG filling stations in Europe

LNG public stations in Spain

Name	Owner	Address	Town	Province	Fuel delivered
HAM	HAM	N-II. Km. 582	Abrera	Barcelona	LNG/CNG
TRANS. MONFORT	MONFORT	C/ Dinamarca. Ciudad del Transporte	Castellón de la P.	Castellón	LNG/CNG
HAM	HAM	N-II, Km. 117. E.S. Petromiralles	Torremocha del C.	Guadalajara	LNG/CNG
GN TRUCK	VICUÑA	N-I, Km. 419	Olaberria	Guipuzcoa	LNG/CNG
GNF	GNF	Pol. Ind. El Segre	Lleida	Lleida	LNG/CNG
BIONET	HAM	C/ Sofre nº 3. Políg Ind Riu Clar.	Tarragona	Tarragona	LNG/CNG
VIA AUGUSTA GAS	VIA AUGUSTA	N-II, km 328	Zaragoza	Zaragoza	LNG/CNG
GHC	GNF	N-III Km 11,8	Rivas	Madrid	LNG/CNG
J. SANTOS	GNF	N-II Km. 47,5	Alovera	Guadalajara	LNG/CNG
DISFRIMUR VALENCIA	GNF	Ribarroja	Valencia	Valencia	LNG/CNG
DISFRIMUR ALICANTE	GNF	San Isidro	Alicante	Alicante	LNG/CNG
EUROCAM	GNF	N-I	Vitoria	Alava	LNG/CNG

Biggest in Europe

LNG public stations in Portugal

Gold Energy	Mirandela	Tras os Montes	LNG/CNG	Opening end 2012
Gold Energy	Maia	Porto	LNG/CNG	Opening end 2012

LNG public stations in The Netherlands

Vos Logistics	Oss	Noord Brabant	LNG	
Salland Ollie	Zwolle	Overijssel	LNG	Need special card
De Kock	Oss	Noord Brabant	LNG/CNG	Oct. 2012. Need sp. card
Rolande LNG	Tilburg	Noord Brabant	LNG/CNG	Oct. 2012. Need sp. card

LNG public stations in Italy

Concess. TotalErg (costr. Vanzetti)	Borgata Marocchi statale 29 km 24 + 570	Poirino	Torino	LNG/CNG	LNG refilling not yet available
Concess. Esso (costr. HAM Italia)	via Prati, 24/a	Calderara di Reno	Bologna	LNG/CNG	LNG refilling not yet available
Concess. ENI R&M (costr. Vanzetti)	via Circonvallazione Est, 18/a	Villafalletto	Cuneo	LNG/CNG	LNG refilling not yet available
Kostner GmbH (costr. Vanzetti)	via Brennero (SS 12) uscita autostr. Varna	Varna	Bolzano	LNG/CNG	LNG refilling not yet available
Concess. ENI R&M (costr. HAM Italia)	via della Borghesiana	Roma	Roma	LNG/CNG	LNG refilling not yet available
F.lli Ratti (costr. Vanzetti)	Strada Statale per Voghera, 75	Tortona	Alessandria	LNG/CNG	LNG refilling not yet available

LNG public stations in Sweden

Fordonsgas	Göteborg	Göteborg	LNG/CNG	
Statoil/AGA	Järna	Södertälje	LNG/CNG	
Preem/E.ON	Malmö	Malmö	LNG	

LNG Blue Corridor. 29 partners (10 Iberian)

GERMANY	Erdgasmobil Bohlen & Doyen
NETHERLANDS	Ballast Nedam
UK	Gasrec Hardstaff Group Linde
BELGIUM	Fluxys Drive Systems VITO
AUSTRIA	Salzburg AG

ITALY	Eni CRF
FRANCE	GNVert Westport Innovations (Canada/France) RTS Renault Trucks
SWEDEN	Swedish Gas Association Volvo Technology
SLOVENIA	ENOS
CROATIA	EIHP



L-CNG infrastructure in Europe



L-CNG filling station in Göteborg (Sweden)



L-CNG filling station in Lleida (Spain)

From the North to the South, from the West to the East, we have to implement the European L-CNG infrastructure that will allow us to reduce the oil dependence.





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