Natural Gas as an alternative fuel for road and maritime transport

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Secretario General

GASNAM, Is the Iberian Gas Association of all the players around the use of natural gas as a fuel. We count members from the gas industry, logistics, gas equipment industry, engineering, vehicle & engine producers, national and regional Administration entities and fleet owners.

Our activities are split in two sections: terrestrial and maritime.

Worldwide gas reserves
Unit: (10^9 m^3)

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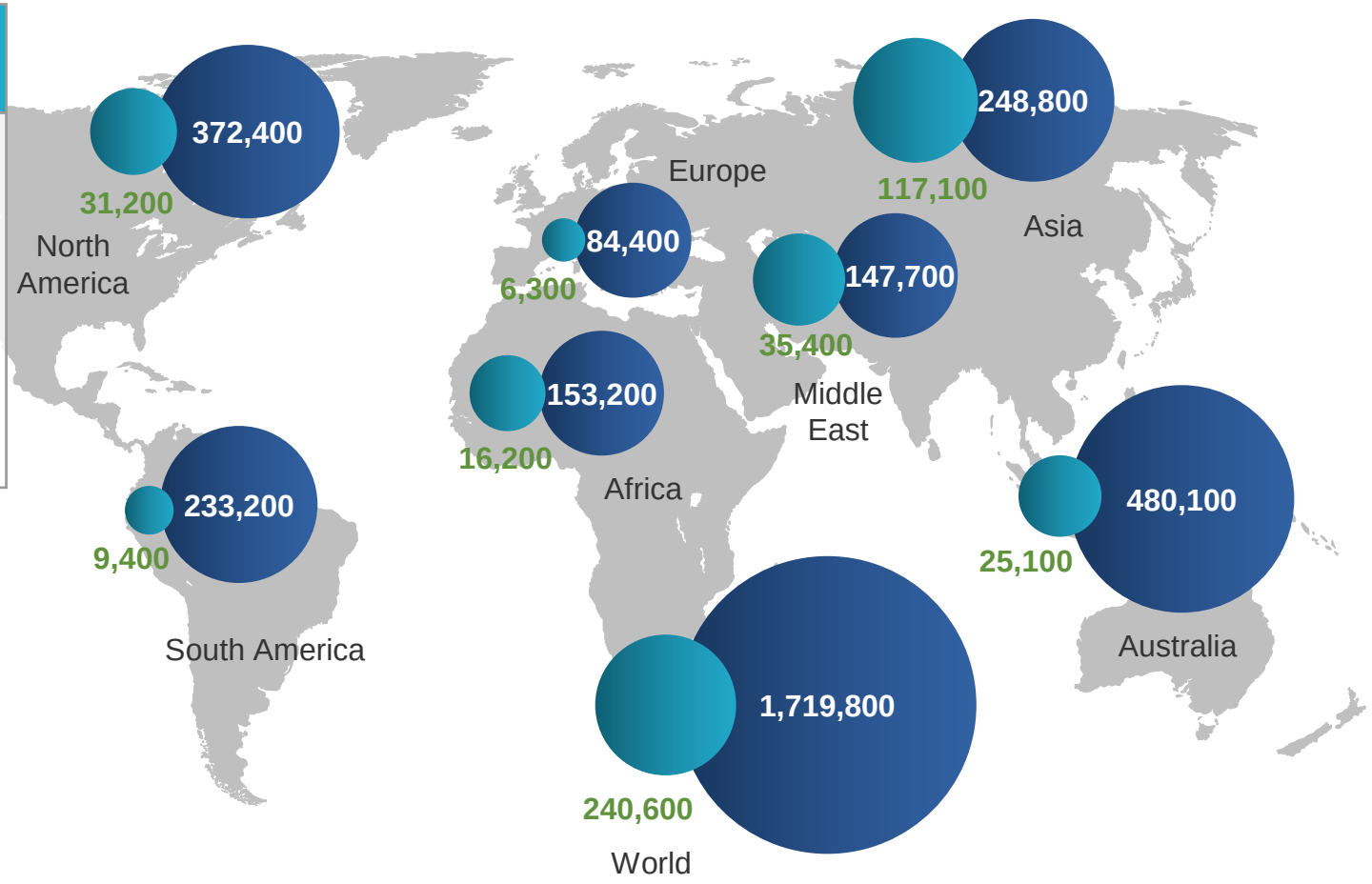
Gas consumption worldwide

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

Natural gas natural can fuel any type of transport

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CNG

LNG

Cars, vans, light trucks, urban buses, refuse collection trucks, distribution trucks

Long distance heavy trucks, coaches, non electrified railways and ships

- Natural gas is the only alternative to oil derived fuels for any type of transport and mobility use
- CNG is the **recommended urban fuel** (taxis, delivery, refuse, buses **+ ship auxiliary engines**)
- LNG will become the **future professional fuel**.

Eurogas Roadmap 2050 (2011)

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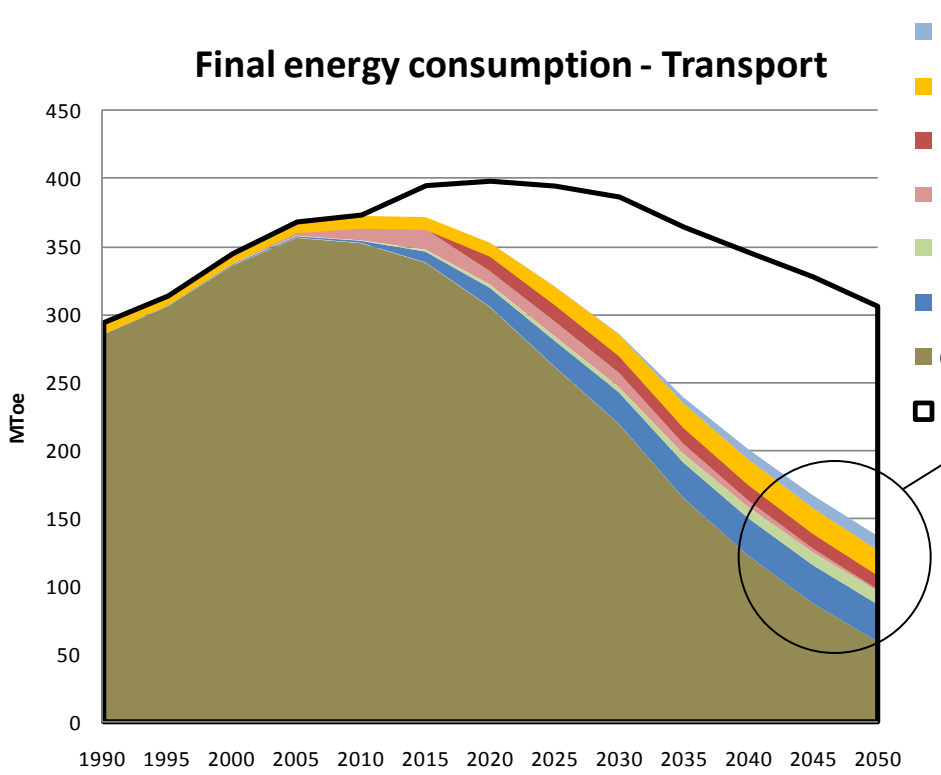
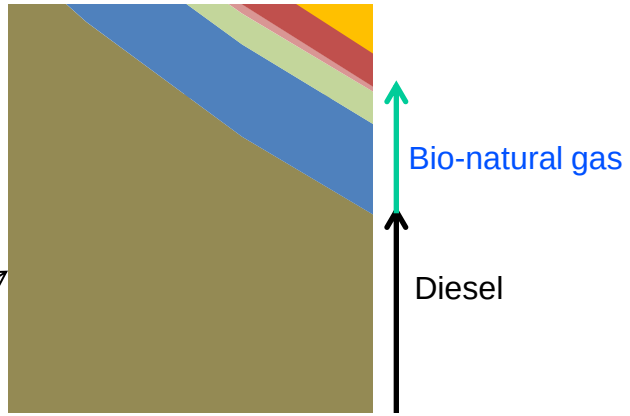
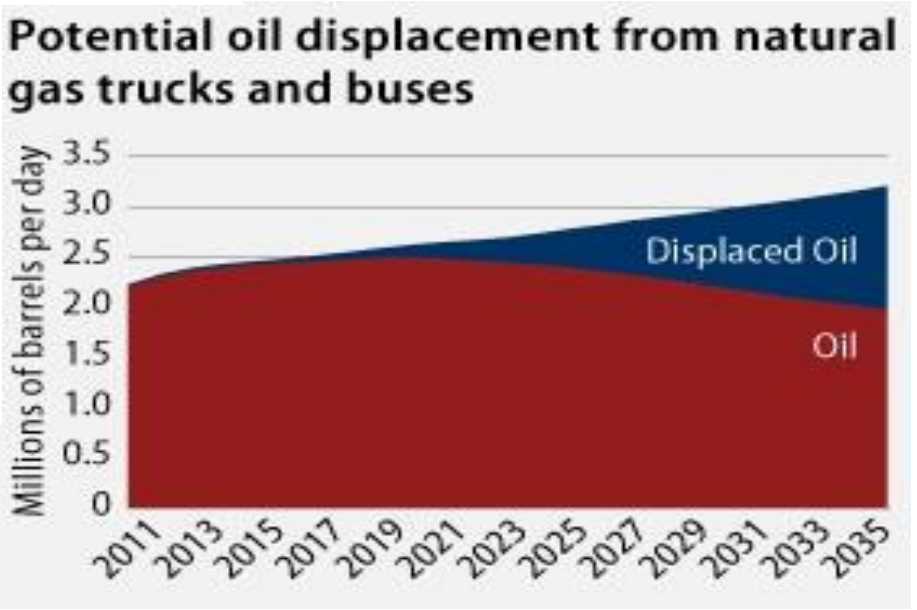
Expected market share: 9% in passenger, 33% freight



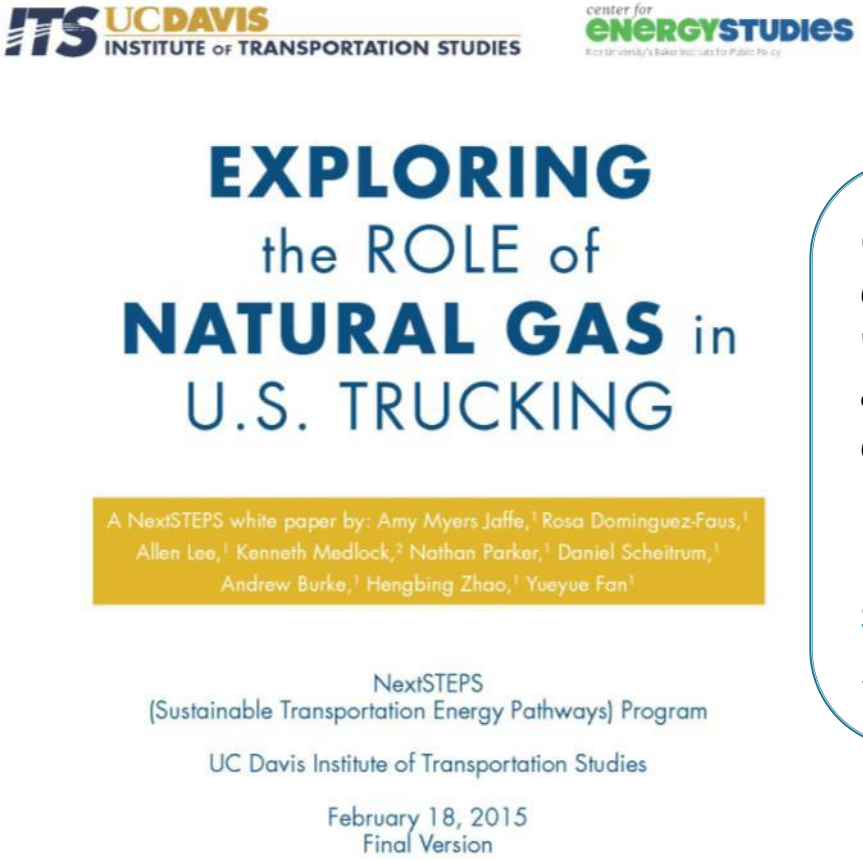




North American forecast: 37%

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

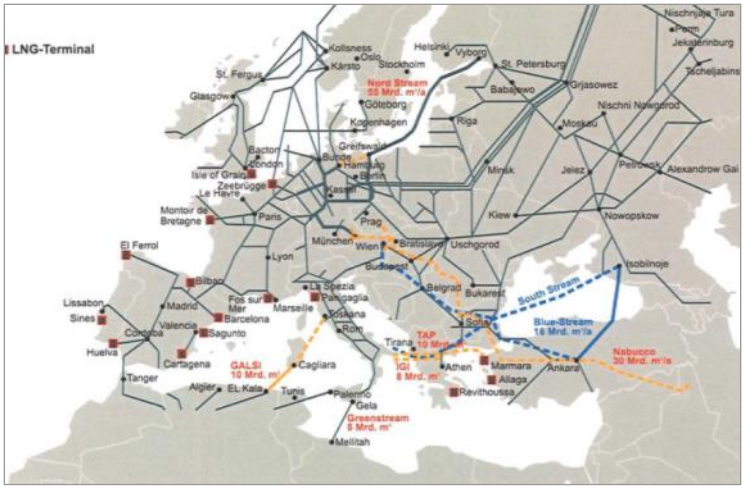
New American forecast



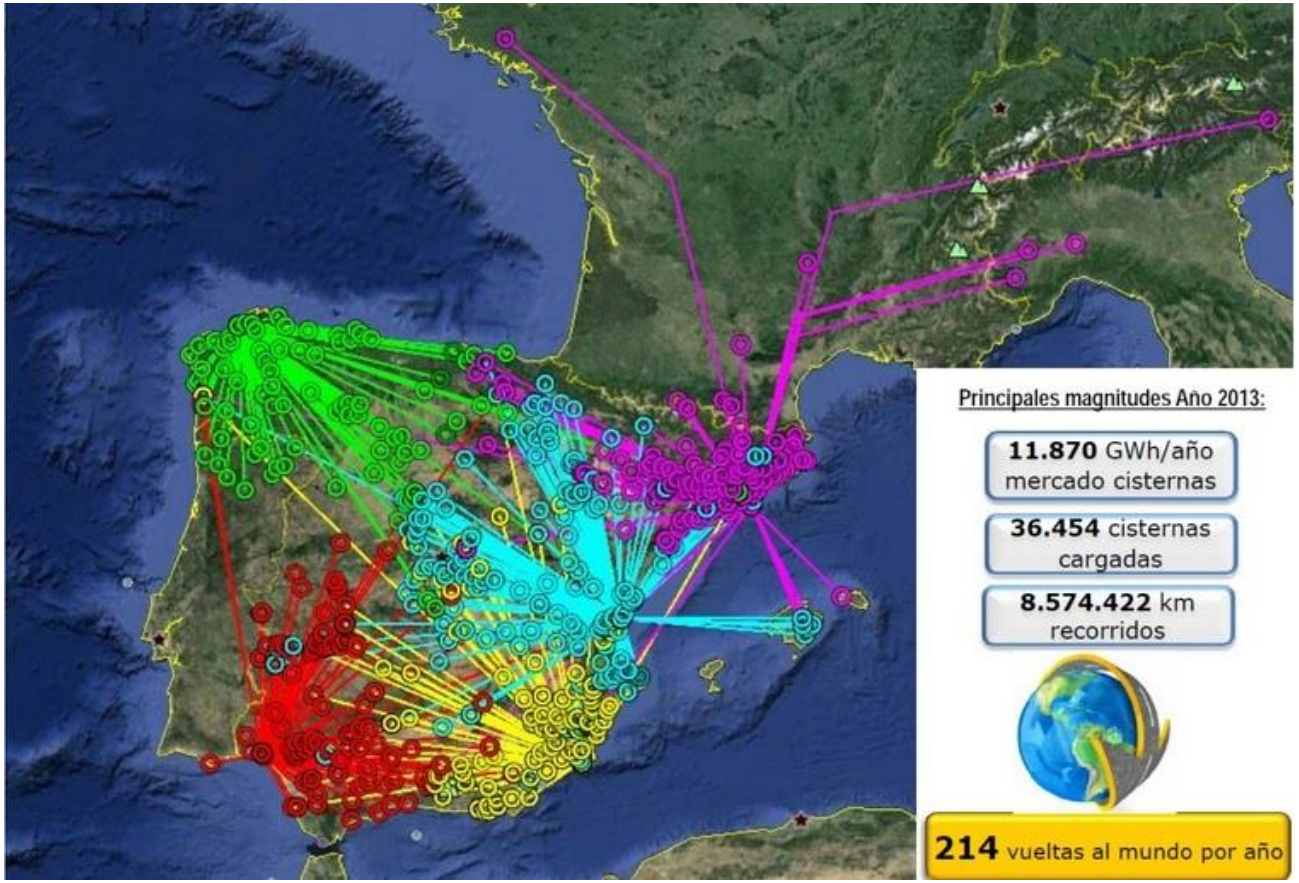
Commercial forecasts for how much natural gas could replace oil in transportation vary widely, with high end estimates in 5% to 10% of the total available market of about 25% to 50% of the existing market for diesel.

Las nuevas previsiones apuntan a una sustitución del diesel de entre el 25 y el 50% a medio plazo

NG supply to Europe
Pipelines and LNG



Iberian map of LNG terminals



Spain is the most experienced European country in LNG transport and logistics.
36.000 LNG tank loads have been moved in 2014

Source: Enagás

CNG technology in light vehicles

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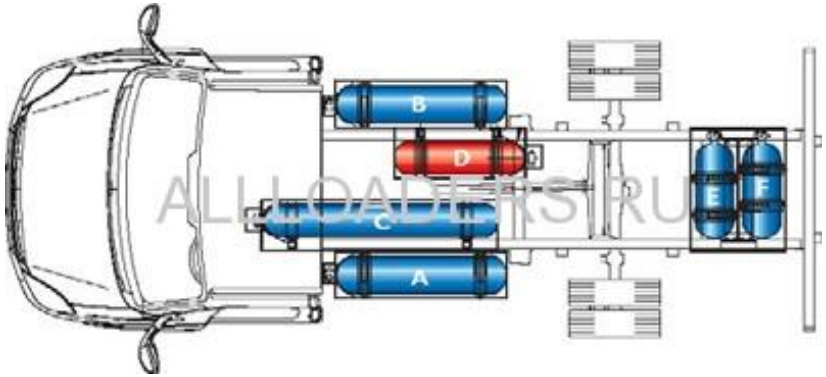
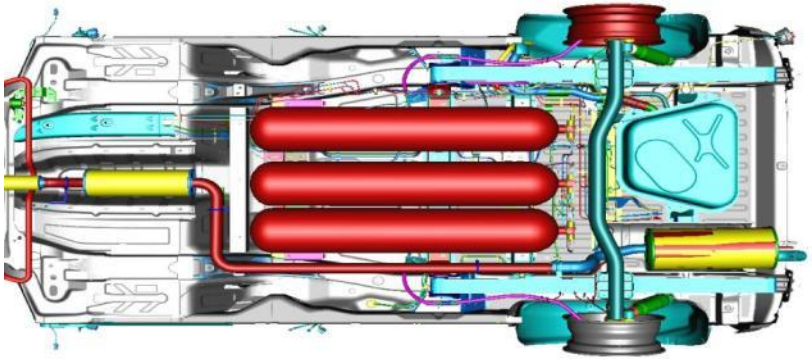
Underneath tanks keep the inside space for passenger and luggage

Montaje de los depósitos bajo el piso en las versiones CNG de los SEAT León y SEAT Mii



Depósitos en el chasis del Iveco Daily CNG



Otro tipo de montaje bajo el piso

GNC is the *recommended urban fuel*

The development of heavy vehicles with CNG has been limited to urban services with daily refilling, due to the weight and volume of the CNG bottles. These are the current use of the garbage collection vehicles and urban buses, both with a power around 300 CV.

Out of the 70.000 urban buses in service in the main European cities (Italy, France, Germany, Spain, Sweden, Greece, Portugal, Holland), **9.000 (13%) use GNC.**

Out of the 20.000 garbage collection trucks in service in Europe (France, Spain, Italy, Greece), **3.000 (15 %) use GNC**.

Biomethane production in Madrid is enough to fuel the 800 GNC urban buses

Natural gas/biomethane vs. diesel

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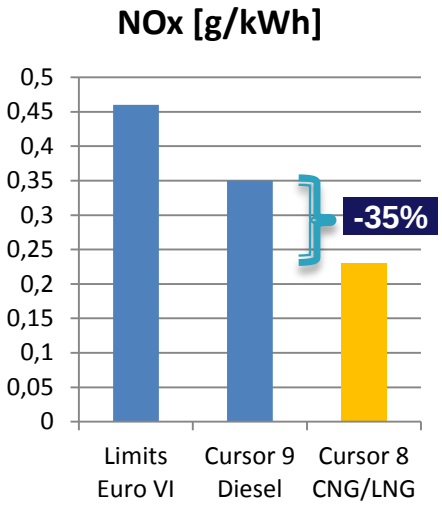

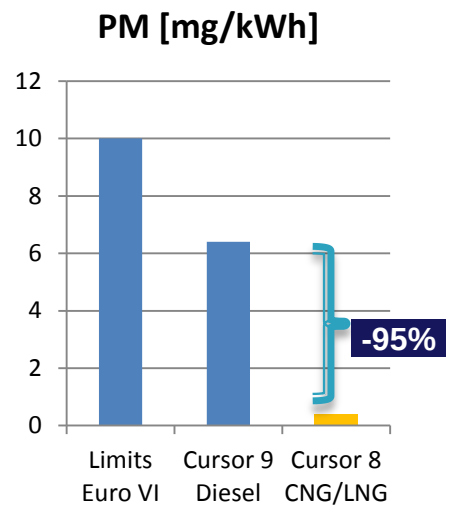

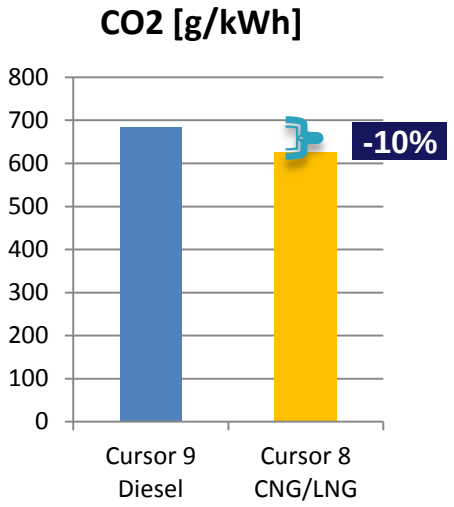

Natural gas (fossil)
CO_2 up to -10%

Biomethane
CO_2 neutral

CNG and LNG

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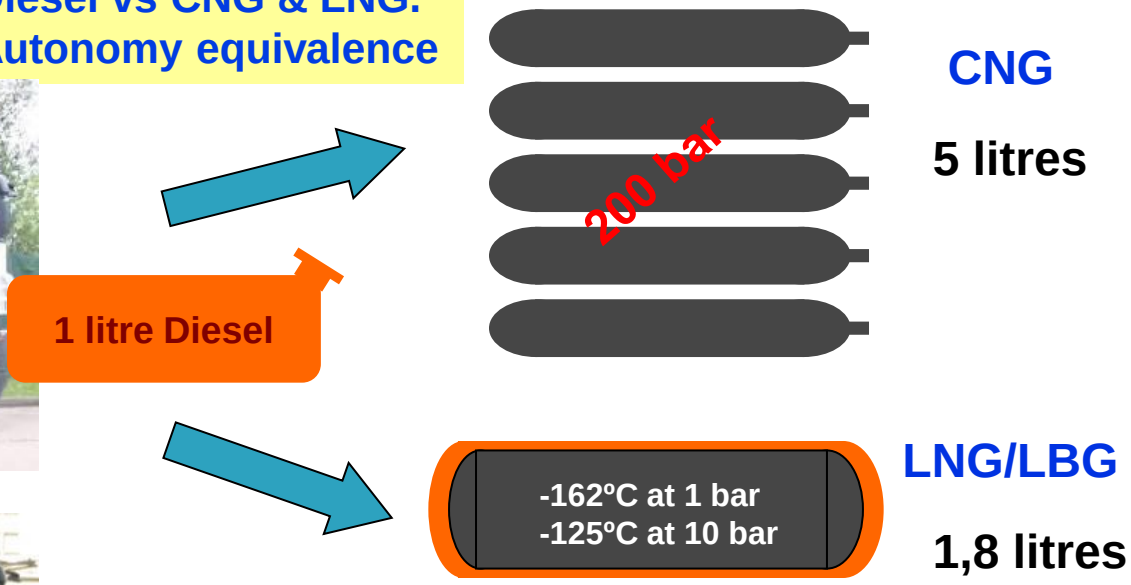
Diesel vs CNG & LNG. Autonomy equivalence



- CNG vehicles have a limited autonomy of 300-400 km
- LNG increases this autonomy up to 600-700 km with a single tank and to 1.000 km with two tanks
- LNG, coming directly from LNG port terminals, is cheaper than CNG
- LNG availability is independent from gas grid

LNG opened the way to use natural gas in long distance trucks

Long distance LNG trucks

Iveco Stralis 330 HP LNG

Scania LNG 340 HP

Urban services and distribution
CNG trucks

MAN CNG chassis

Renault CNG truck

Volvo CNG truck

IVECO CNG truck

American trucks running on LNG

Autocar
International
Freightliner
Peterbilt
White
…

More than 39.500 LNG trucks are in service in USA, in all type of applications. 14.000 new registrations in 2014. (Source NGVAmerica)

Chinese trucks running on LNG

Foton

Shaanxi

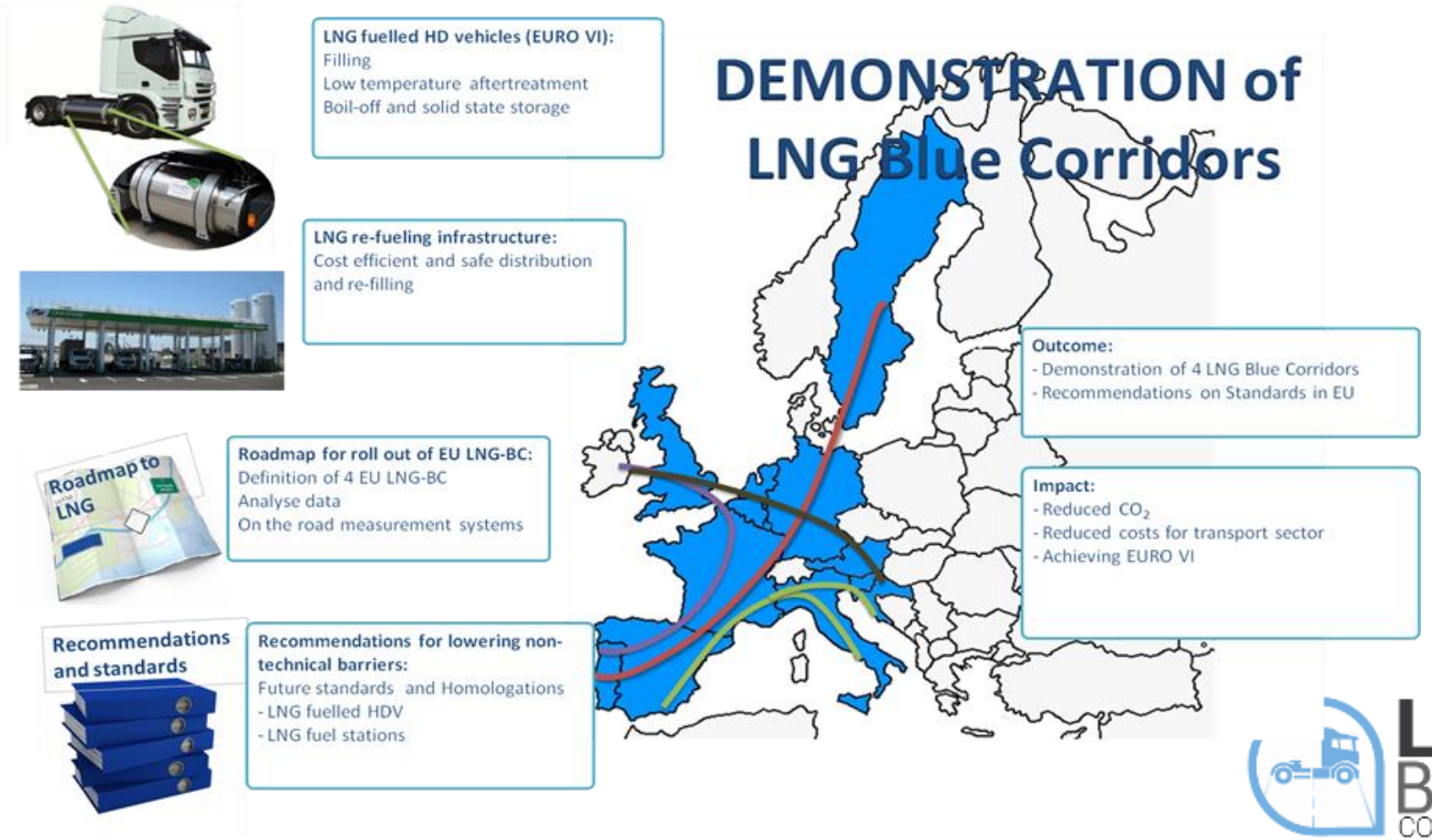
Sinotruk

Dong Feng

Today: More than 240.000 trucks and buses are running on LNG, with a network of 2.400 fuelling stations

2016: Plans for 1.600.000 total GNVs and 5.000 fuelling stations. Forecast sees 5.000.000 GNVs in 2020. (Source ENN China)

LNG Blue Corridors project



- **27 industrial partners during a 48-month project. www.lngbluecorridors.eu**
- **100 new LNG trucks and 14 LNG new refuelling stations**

Source: LNG Blue Corridor project

Spain: GNL+GNC filing stations plan

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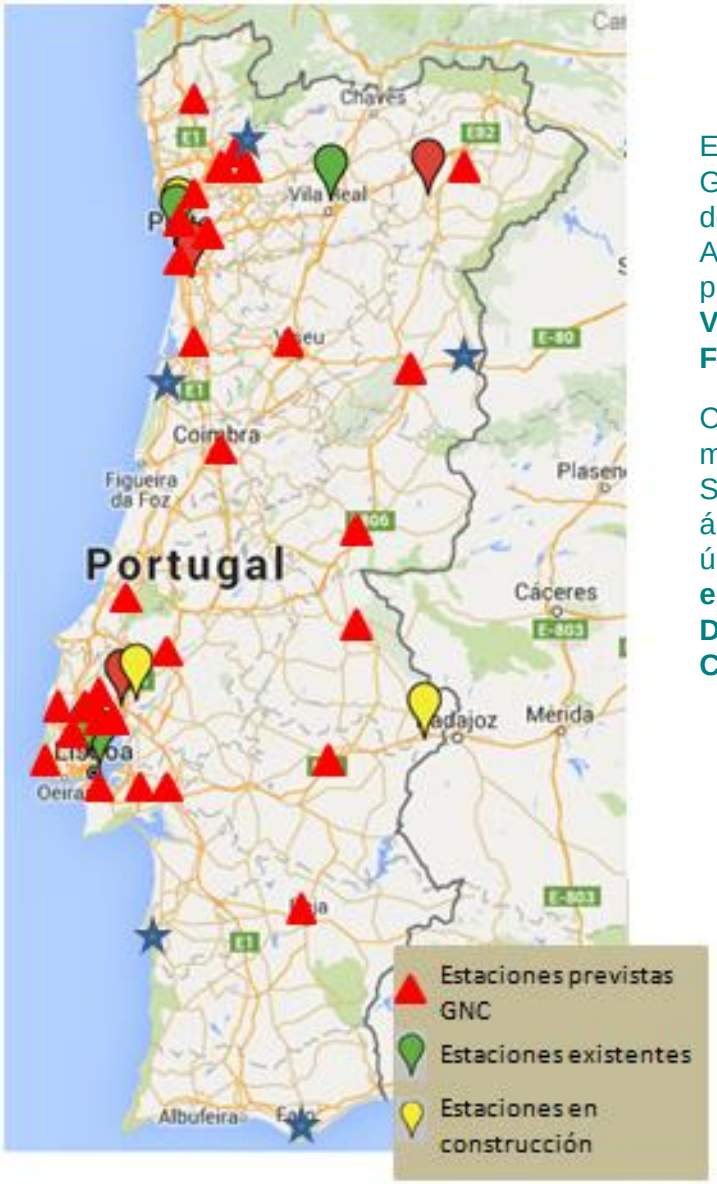
Necesarias en municipios:	**134**
Existentes	- 27
Previstas TEN-T	- 10
Por construir:	**97**
Otras ciudades	17
Ciudades fronterizas	4
Distancias > 212 km	3
Adicionales:	**24**
Total GNC	**121**
GNL/GNC del TEN-T	**20**
Total a construir	**141**

Además de los municipios de >100.000 hab. ya identificados, existen 21 puntos entre capitales de provincia y otras ciudades importantes que hay que incluir: **Santiago de Compostela, Lugo, Pontevedra, Huesca, Gerona, Soria, Palencia, Zamora, Segovia, Ávila, Guadalajara, Teruel, Cuenca, Toledo, Cáceres, Trujillo, Ciudad Real.** Por otra parte **Irún, Figueres, Ayamonte y Tuy por su condición de fronterizas.**

Con estas estaciones las únicas distancias mayores de 230 km entre puntos serían: Zaragoza-Barcelona: 286 km; Zaragoza-Guadalajara: 260 km; Huelva-Badajoz: 254 km. Con **3** estaciones más en: **Fraga, Calatayud y Fregenal de la Sierra** se resuelve el problema**. Total 24 estaciones.**

De esta forma dejaríamos como máxima distancia los 212 km entre Cáceres y Salamanca, perfectamente admisibles si tenemos en cuenta que la autonomía de los turismos de GNC es de más 300 km.

Portugal: GNL+GNC filing stations plan



En las localidades de >100.000 habitantes se dispondrá de una estación de GNC, identificando así **tres área metropolitanas, Porto, Lisboa y Braga**, donde serán necesarios **4, 11 y 4 puntos de suministro** respectivamente. Además de los municipios de >100.000 hab. ya identificados, existen además 14 puntos entre las capitales de distrito: **Viana Castelo, Braga, Braganza, Aveiro, Viseu, Guarda, Coimbra, Castelo Branco, Leiria, Santarém, Évora, Beja, Faro.**

Con estas 33 estaciones todas distancias son menores de 150 km, distancia máxima que considera el plan TEN-T entre estaciones.
Si tenemos en cuenta las estaciones mixtas GNC-GNL, antes comentadas, en el área metropolitana de Braga, si situamos la estación mixta en Braga, únicamente serían necesarias 32 estaciones GNC en Portugal. **Total 32 estaciones.**
De esta forma dejaríamos como máxima distancia los 168 km entre Leiria y Castelo Branco.

Necesarias en municipios:	44
Existentes:	-7
Previstas GNL/GNC muni.:	-5
Por construir GNC	**32**

De estas 32 ya hay 3 en construcción, que son las marcadas en amarillo.

GNL in railways

Locomotora experimental rusa con turbina de gas de 11.000 CV.

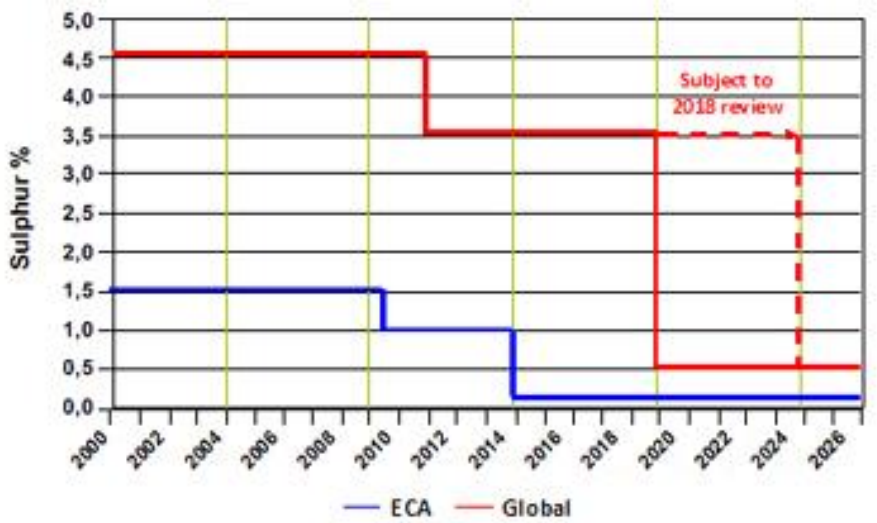
Locomotora rusa de maniobras. 1.200 CV

Canadian LNG locomotives

Ferrocarril Central Andino. Perú
Locomotive working with CNG

21

LNG in shipping.
Sulphur limit on 0,1% in ECAs



Installation of a LNG auxiliary engine in the Abel Matutes ferry

LNG engine an cool box for the Abel Matutes ferry

Comparative emissions LNG vs HFO

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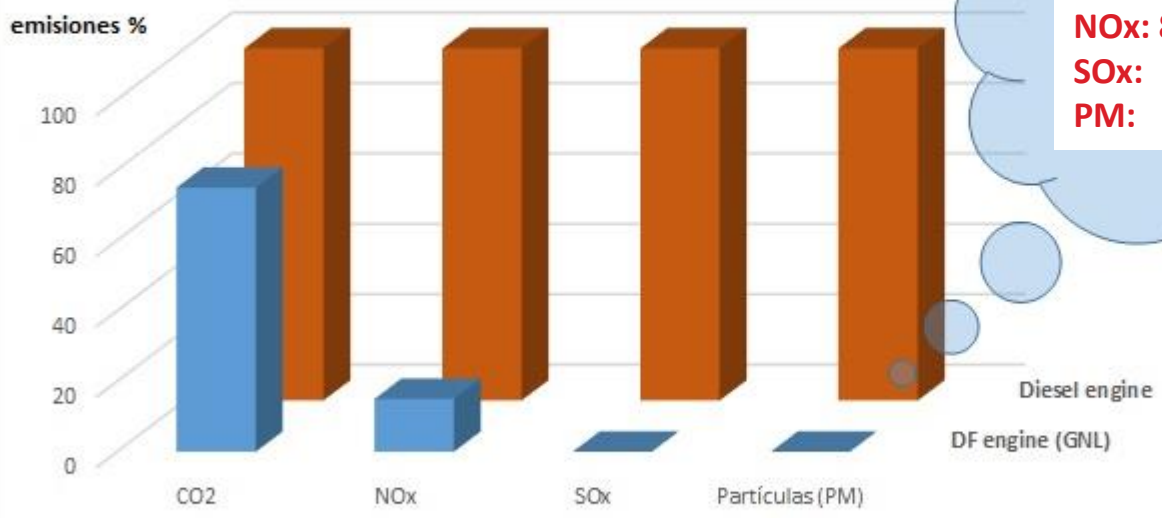
Environmental advantages of the NG



Emissions NG vs HFO:

CO2: 25% less
NOx: 85% less
SOx: Elimination
PM: Elimination

Fuente:

Comparative emissions LNG vs MDO

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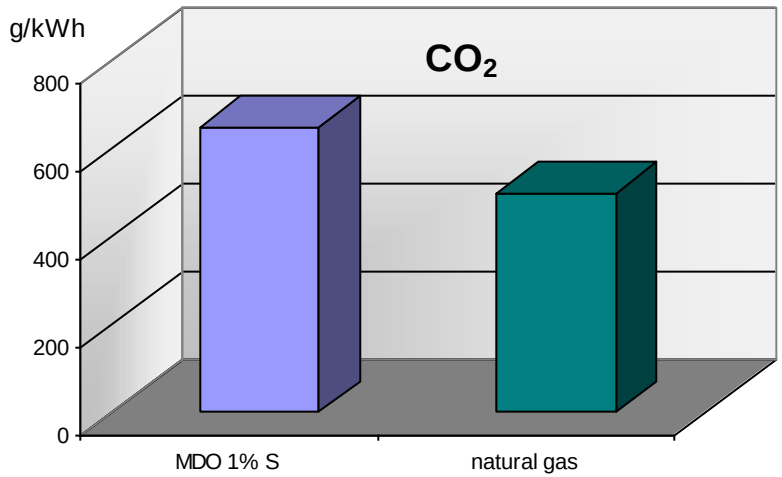
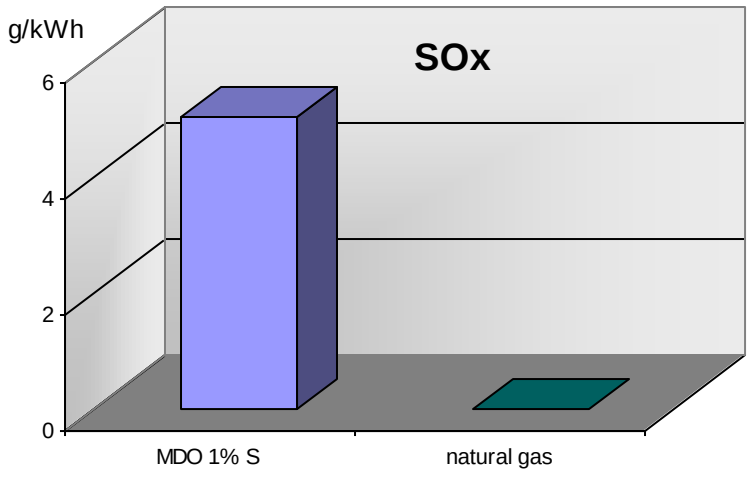
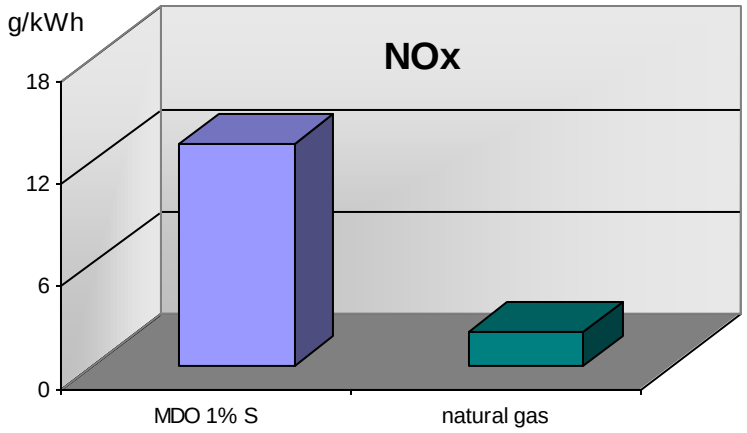
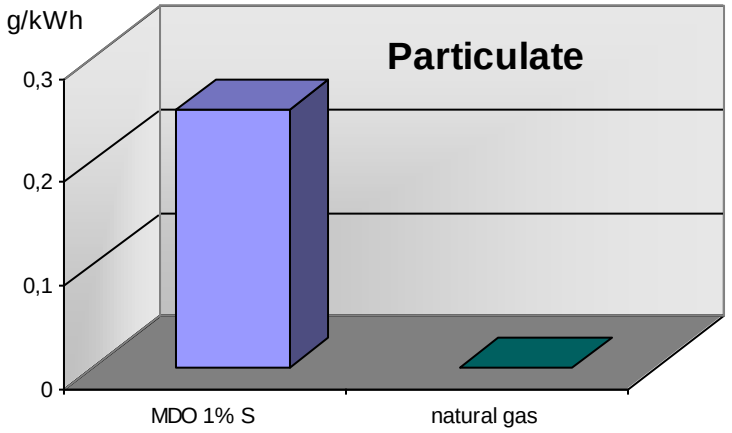
Emission comparison between MDO 1%S vs. LNG









Emission reduction

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TOTAL REDUCTION (TONS/YEAR)				
PORT		NOx	CO_2	SO_2
Barcelona	Port Stay	22,04	1464,79	2,16
	Maneuvering	8,08	537,34	0,79
Palma	Port Stay	22,24	1477,79	2,18
	Maneuvering	8,08	537,34	0,79
TOTAL		60,44	4017,13	5,933

FUEL COSTS WILL BE REDUCED A 35% BY USING NATURAL GAS INSTEAD OF DIESEL DURING PORT STAYS

LNG ships being built in Spain

- 3 tug boats in **Astilleros GONDÁN** (Castropol)
- 2 ferry boats in **LaNaval** (Sestao)
- 2 cable ships in **LaNaval** (Sestao)

- **7 of the 15 ships being built in Spain today are fuelled with Natural Gas.**

- Memorandum of understanding signed between Baleària and Construcciones Navales del Norte (**LaNaval**) **to build two new ferries of 235 m length and 30,4 m breadth**

  Propelled by dual fuel engines which can operate with natural gas or diesel enabling the company a reduction of CO_2 emissions by more than 30%.

Spanish experiences in LNG Bunkering

- First LNG Bunkering June 2012, Algeciras port.
  Truck to ship. 4 hours to bunker 40 tonnes LNG

- LNG Bunkering February 2014, Cartagena and Vigo ports.
  Truck to ship. Bunker 45 m3 LNG

Spanish experiences in LNG Bunkering

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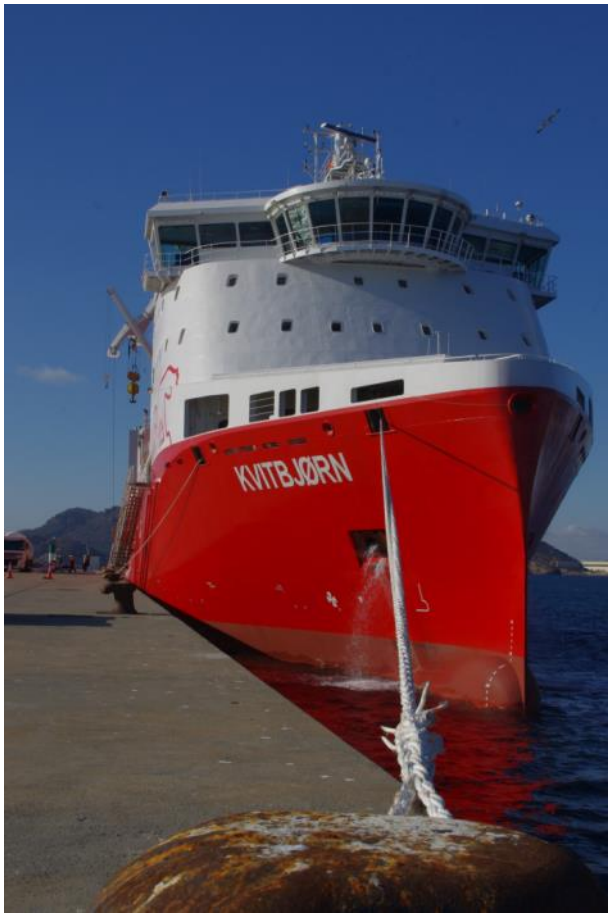
- Recent LNG Bunkering. March 2015. Cartagena port.
  Truck to ship. 7 trucks → 315 tonnes LNG



Spanish draft standard LNG Bunkering

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1. Requirements for the supply
    a. Operation design
    b. Certifications
    c. Responsibilities
    d. Communication system
    e. Compatibility facilities and ship
    f. Conditions for eventual leakages
    g. Safety enforcement

2. Risk management
    a. Qualitative risk assessment
    b. Safety distances
    c. Result analysis
    d. Quantitative risk assessment (QRA)

3. Personnel qualification and requirement for the equipment
    a. Personnel qualification
    b. Equipment requirements

Spanish draft standard LNG Bunkering

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7 Supplying the LNG
   a. Info exchange
   b. Safety areas definition
   c. Checks
   d. Transfer system connection
   e. Piping and hosing venting and inertization
   f. Transfer system cooling
   g. LNG transfer
   h. Piping and hosing drain and purge
   i. Transfer system disconnection
   j. Removal of the safety areas
8 Safety measures
   a. General
   b. Access and placement of road tanks to the supply area
   c. Safety areas and limits
   d. Cryogenic protection
   e. Elimination of static electricity and galvanic sources
   f. Emergency shut-off (ESD)
   g. Emergency disconnection system (ERS):
   h. LNG leakages control
   i. Fire measures
9 Emergency plan
10 Measurement of the LNG supplied

Bunkering mode ship-to-ship

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Optimal supply range between 60,000 and 380,000 m^3

MAIN CHARACTERISTICS

Length:	84,95m
Beam:	16,25m
Depth:	7,60m
LNG Capacity:	1.000m^3

TRASNSFORMATION BUDGET : 3,500,000 €

Multifuel bunkering barge

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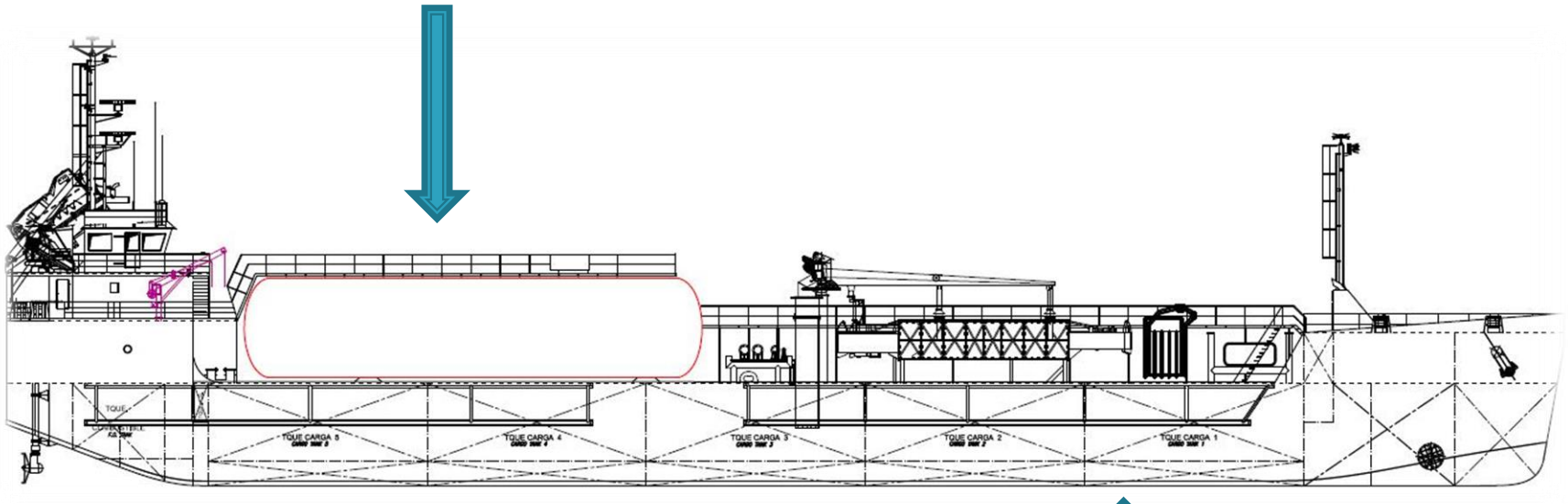
LNG BUNKERING



HFO BUNKERING

MDO BUNKERING

Fuel consumption in different types of vehicles

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A private car, with 20.000-25.000 km per year and an average power of 80-120 CV, uses **1.100 kg of fuel per year.**

An urban bus with 280 CV, doing 50.000 km per year in very demanding traffic conditions, uses **28.000 kg of fuel per year (equivalent to 25 cars).**

A long distance truck, doing some 125.000 km per year, needs **38.000 kg of fuel (1,5 buses, 35 cars)**

A diesel locomotive for medium distances, having a power of 4.000 CV and running 120.000 km per year, uses **190.000 kg of fuel per year (5 trucks, 7 buses, 173 cars)**

A ferry uses **28.000.000 kg of fuel per year (370 trucks, 1.000 buses, 25.500 cars)**

Conclusions

- Natural gas (methane) is an excellent energy vector, with the lowest Carbon to Hydrogen ratio of all the hydrocarbons. Additionally natural gas is a real alternative fuel, having a different origin from the traditional oil derived diesel, petrol and LPG
- Natural gas is used in existing internal combustion engines, with minor additional investments, taking advantage of a well known and mature car & commercial vehicle technology.
- The increasing production of biomethane, both from urban waste and from agricultural stuff is giving natural gas the new and valuable consideration of a renewable fuel
- Natural gas has been used so far as CNG mainly for urban applications. The availability of LNG will spread its use for long distances road and maritime transport
- NG is today the most economic alternative to oil derived fuels, also improving gaseous and acoustic emissions.

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