KIVI

Greenhouse gas Intensity of LNG as fuel

Erik Postma

Delft, 6th December 2017

NGVA Europe at a glance

Advocacy:
Natural and renewable gas as **Transportation Fuel**

*The European stakeholder that **promotes the use of natural** and **renewable gas** as a **transportation fuel** mainly in **vehicles** and **ships***

Industry Platform

*NGVA Europe defends the industry interests to **European decision makers**, to create accurate **standards**, fair **regulations** and equal **market conditions***

*Creates **networks with interested stakeholders** to reach consensus on positions and future actions*

Stakeholders Network

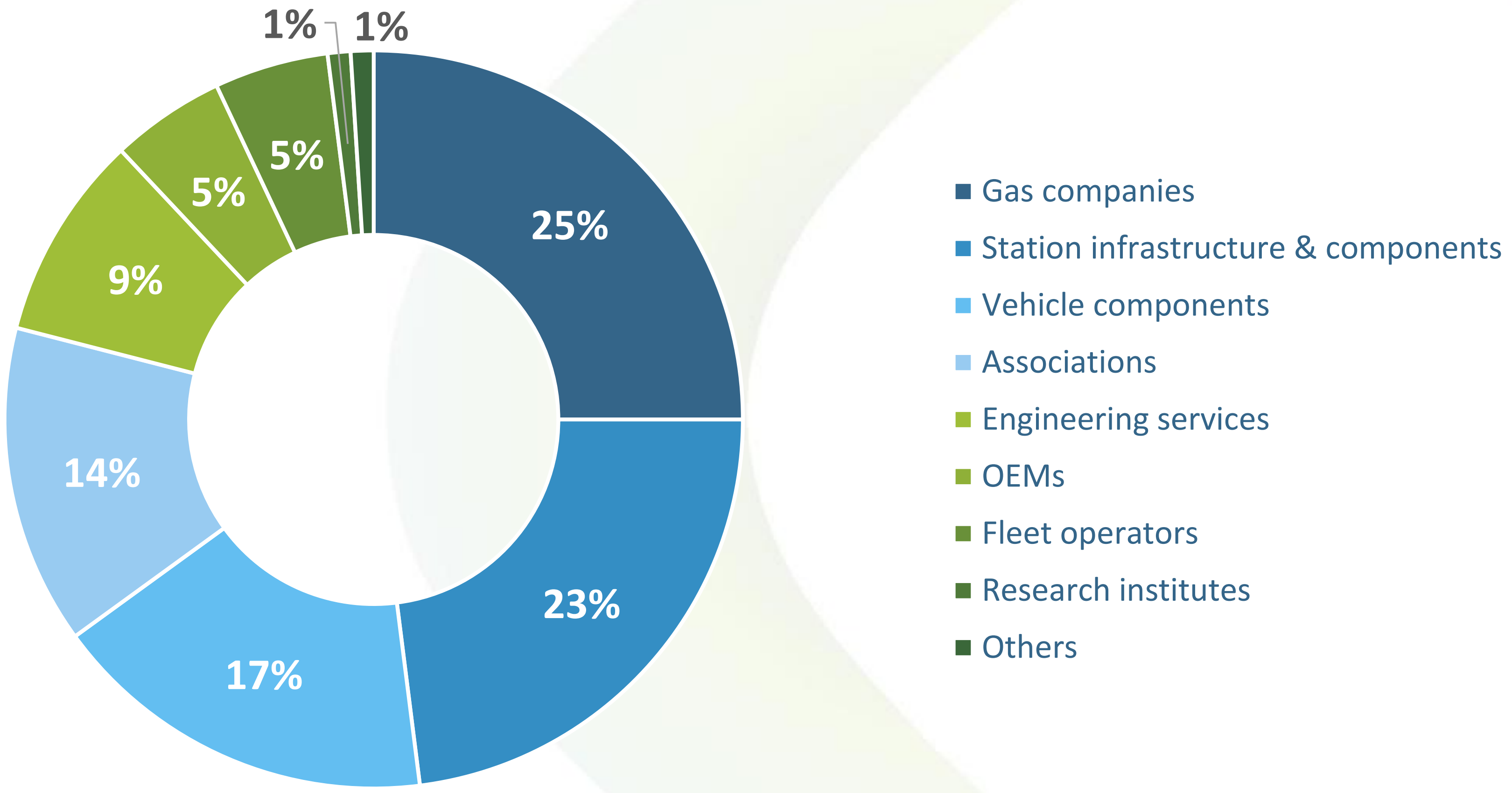
*Collects, records and communicates reliable facts and significant developments in the natural gas vehicle market and provides a **wide European statistical database** about infrastructure, gas consumption and vehicles registrations*

Natural gas Vehicle Market Overview

Members' activities

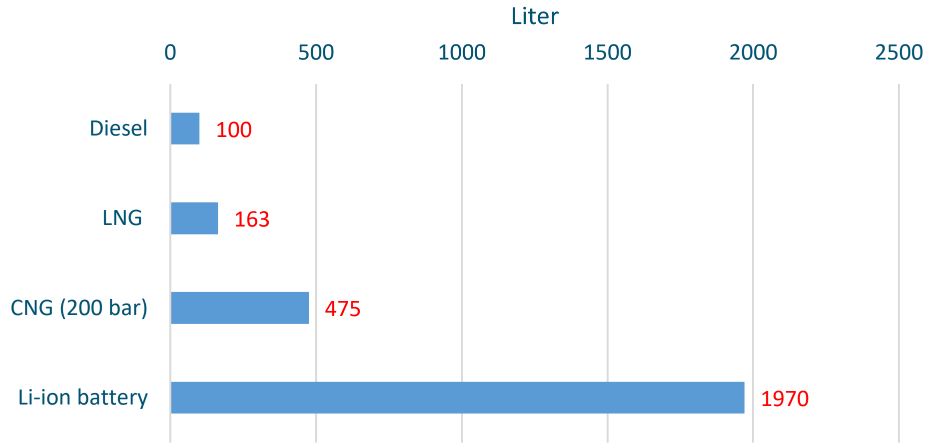
139 members

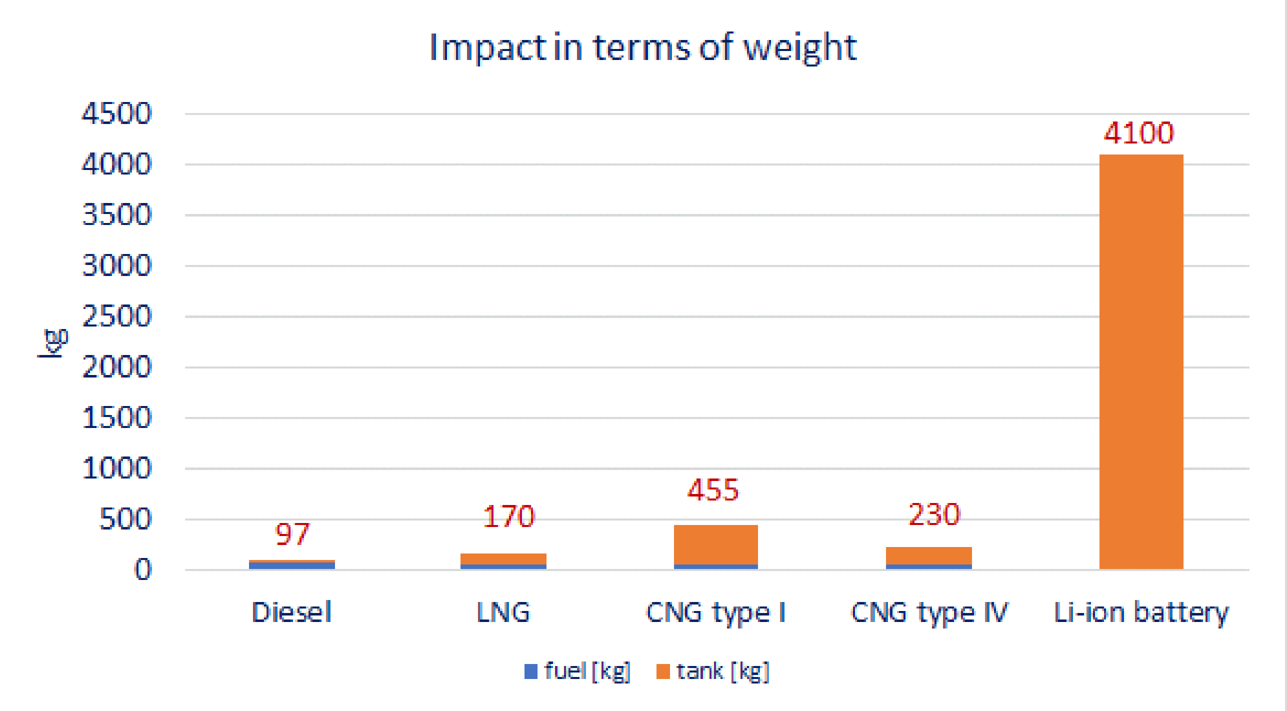
from **31** countries



LNG – a game changer on the transport scenario

Volume needed to replace 100l of Diesel fuel?





LNG – a game changer on the transport scenario

LNG is the only alternative fuel closing the gap with Diesel energy density

LNG – a game changer on the transport scenario

Scania

Iveco

Volvo

3 new LNG engines launched on the market over the last month!

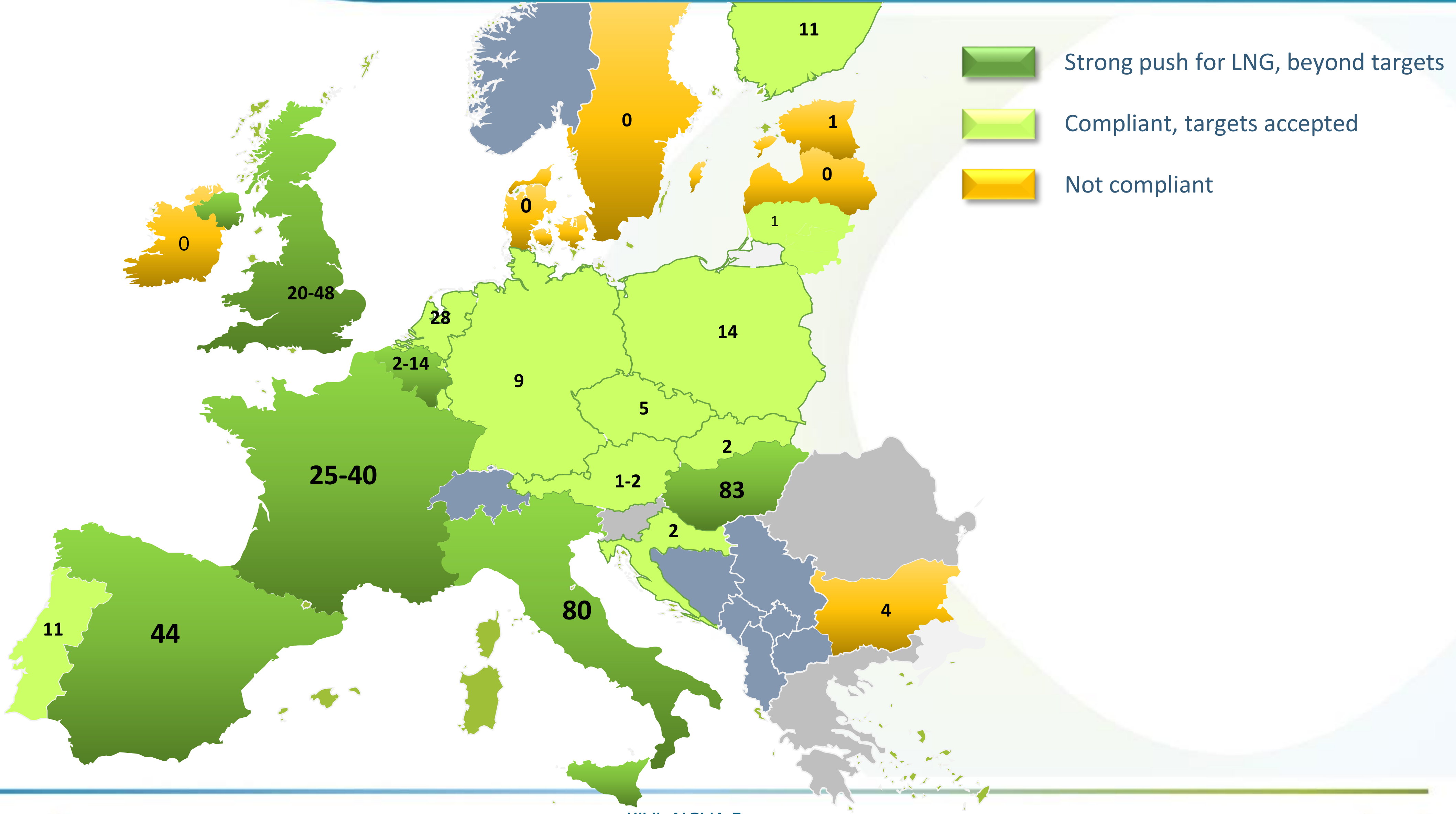
Alternative Fuel Infrastructure Directive – DAFI 2014/94/EU

The Directive was intended to set out minimum requirements for the building-up of alternative fuels infrastructure for powertrains:

- Electric
- CNG & LNG
- Hydrogen

Requirements from National Policy Frameworks	Deadline for implementation
Refuelling points for **LNG** for **maritime applications**	**2025** maritime ports, **2030** inland ports
Refuelling points for **LNG** accessible to the public, at least along the existing TEN-T Core Network, for **LNG heavy-duty motor vehicles**	**2025 –** average distance 400 km
CNG refuelling points accessible to the public in **urban/suburban agglomerations**	**2020**
CNG refuelling points accessible to the public at least along the existing TEN-T Core Network	**2025 –** average distance 150 km

AFI Directive: LNG for road application



LNG Blue Corridors project

www.lngbc.eu

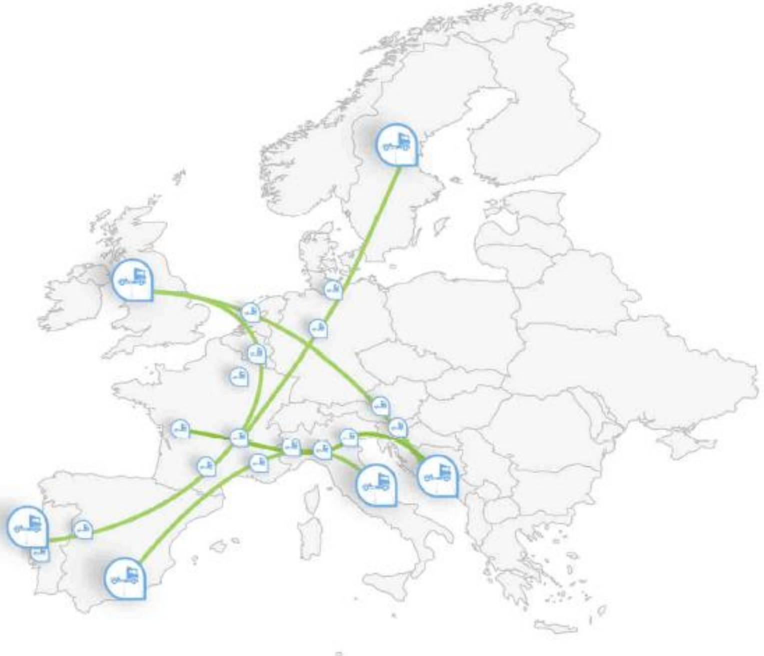
(launched May 2013)

LNG BLUE CORRIDORS

SUPPORTED BY THE EU COMMISSION

SEVENTH FRAMEWORK PROGRAMME

22 Partners



39 Fleet Operators

The LNG Blue Corridors

Applus+ IDIADA

LNG Blue Corridors project

Fleet operators

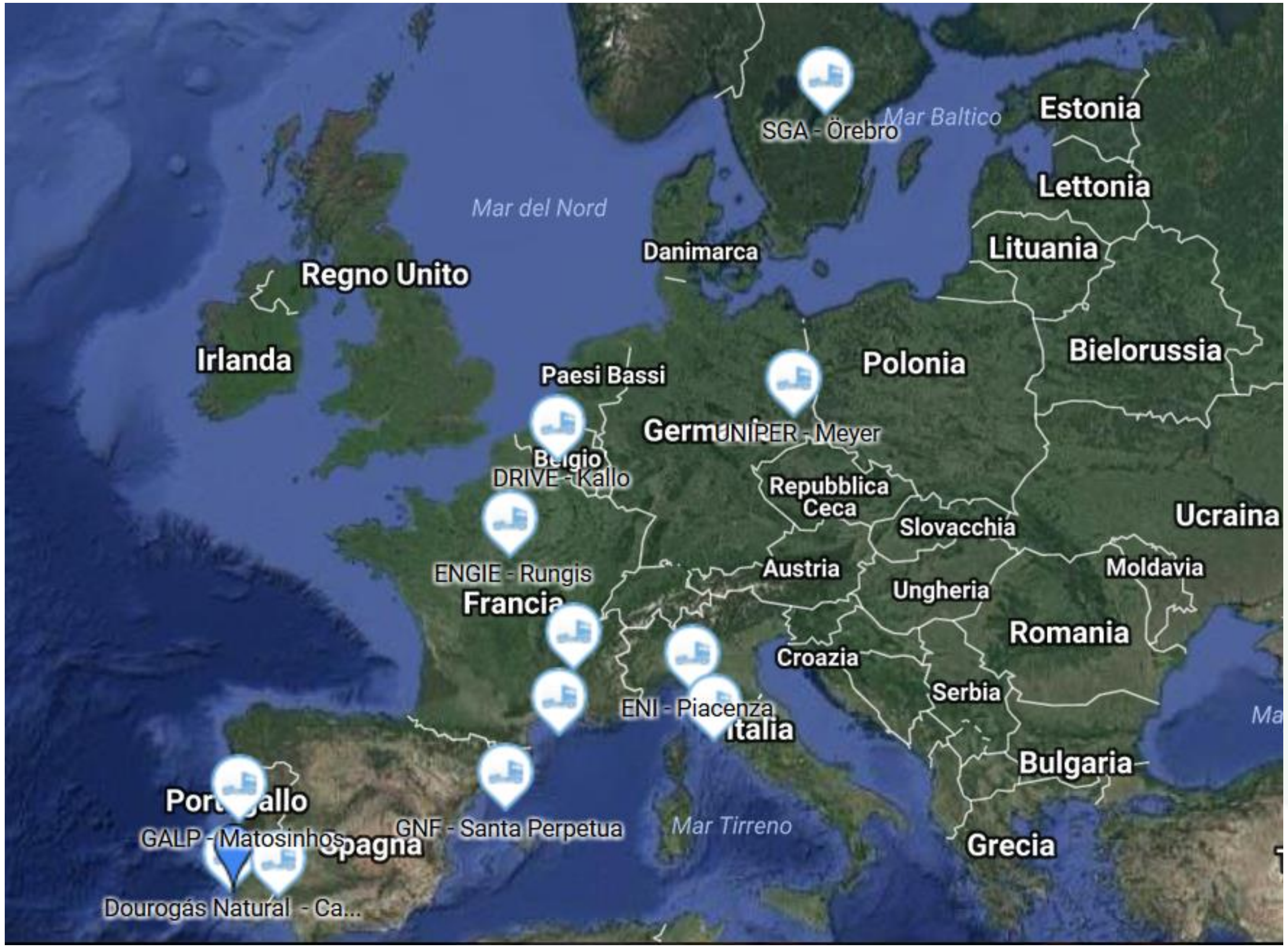
✓ 142 LNG trucks already running

Trucks distribution

- *24 in Portugal*
- *21 in Spain*
- *15 in France*
- *24 in Italy*
- *34 in Belgium*
- *4 in Sweden*
- *20 in Germany*

- More than 25 million kilometer driven
- 142 LNG trucks, 39 fleet operators
- 79,000 refuelling operations
- LNG consumption: more than 10,000 tons over the project period so far

LNG Blue Corridors project



13 LNG stations planned within the project to support the take off of the experimental phase on LNG trucks (Euro V and Euro VI)

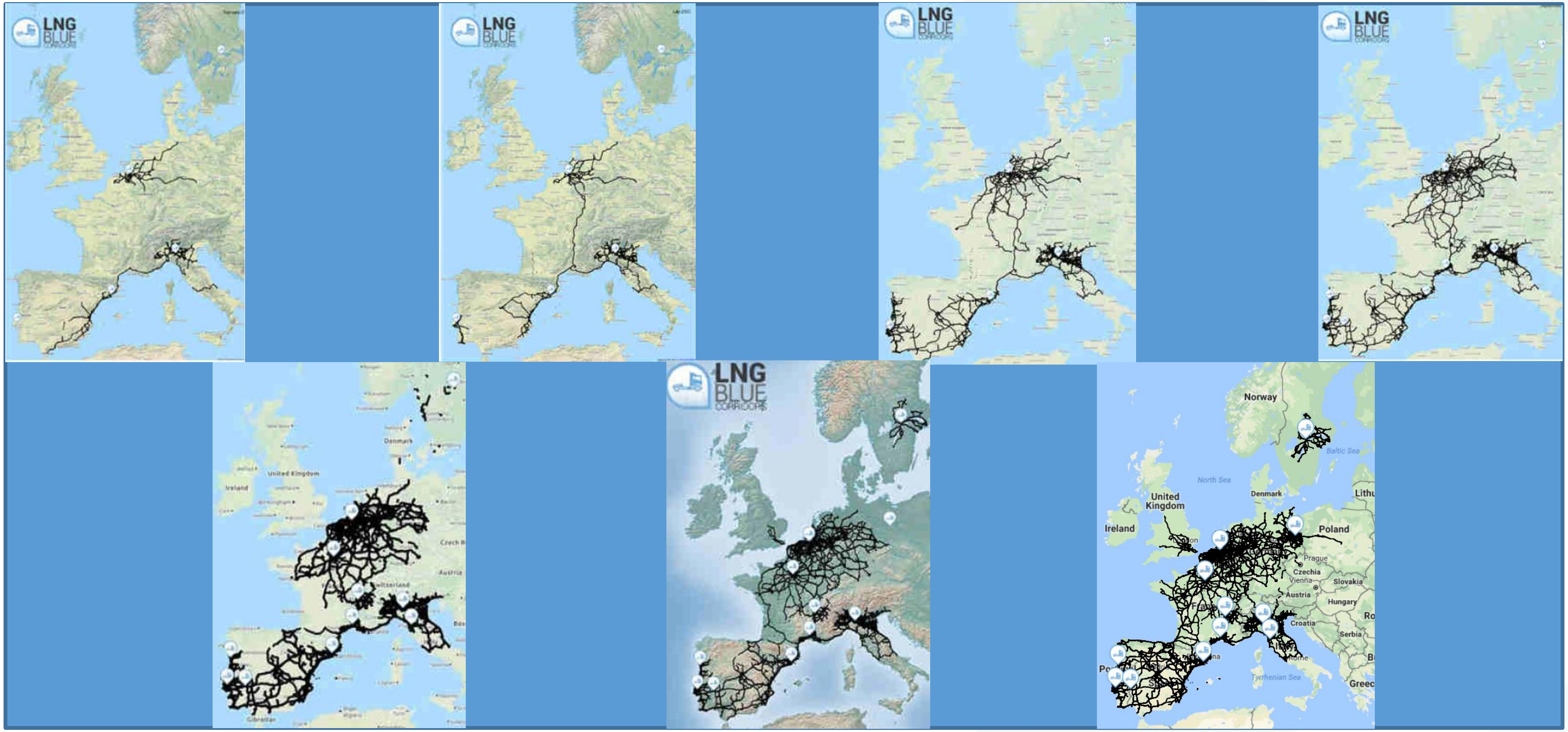
Last LNG BC station to be opened next year in Portugal

Current situation in EU: 120+ LNG stations

Four Corridors

- **Atlantic Blue Corridor**
- **Mediterranean Blue Corridor**
- **SONOR (South to North) Corridor**
- **WE (West to East) Corridor**

LNG truck routes over time 2014 → 2017



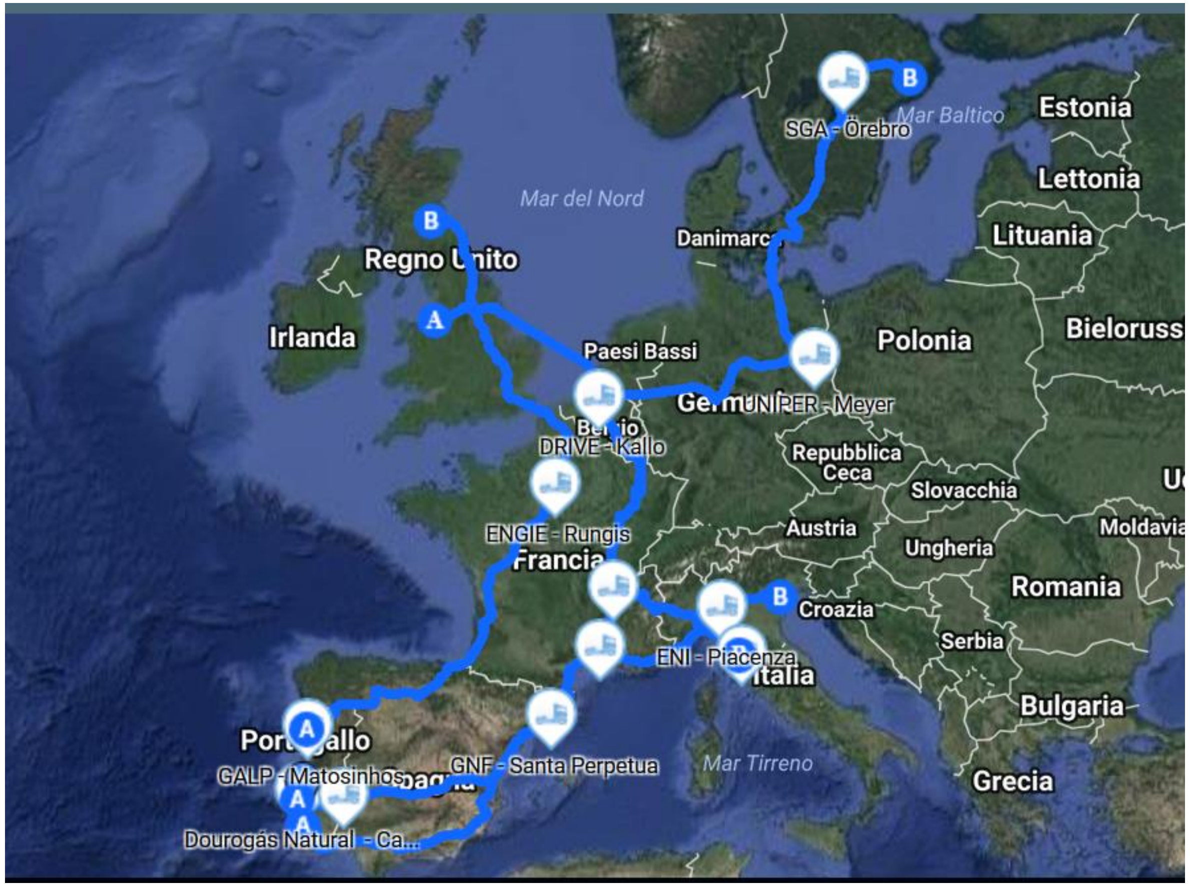
Italian & Spanish fleet

Single LNG tank in black, max range =750km

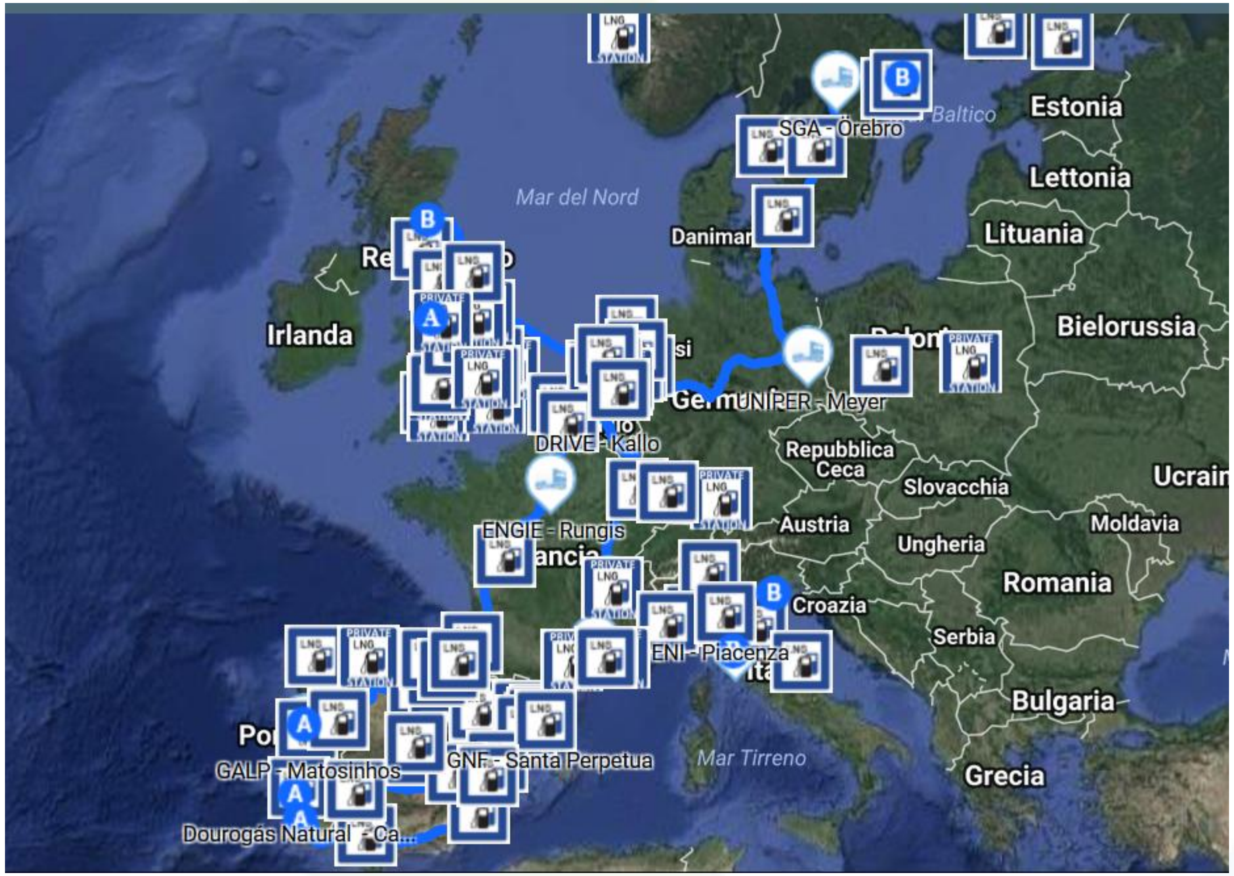
Double LNG tank in red, max range = 1500km

LNG Stations virus EU

LNG BC



Total



LNG infrastructure development

2017: 120+ LNG stations
2020: 100+ planned LNG stations under CEF funding

Interoperability improved by new standards for infrastructure and gas quality:

- LNG filling stations: PrEN ISO 16924:2017
- Gas quality: EN 16723-2: 2017
- LNG connector: EN ISO 12617:2017
- Fuel labelling: EN 16942:2016

- ADR regulation in place for CNG & LNG trucks

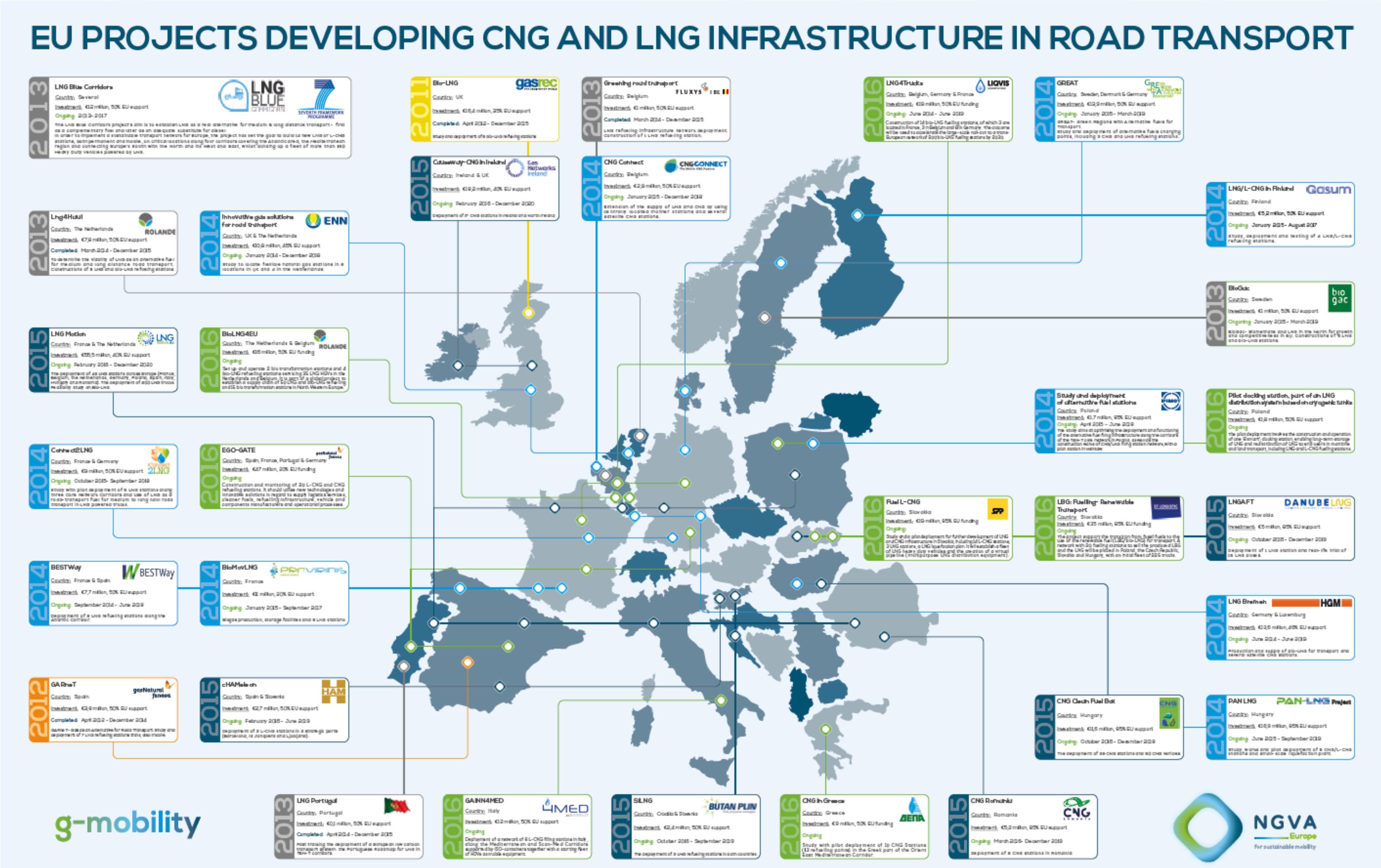
- Open issues/ in development
  - Ferries and tunnels
  - Connection between LNG stations and LNG container trucks
  - EU Standard for LNG vehicle use and operation

LNG standard development

- **CEN TC 408 'Natural gas and biomethane for use in transport'**
  NGVA has joined the supervisory board for H-2020 project on the research topics that were still open:
  - impact of siloxanes on heavy duty engines
  - impact of sulphur on catalytic converters performance of engines
  - impact of oxygen on underground storages
  - impact of components on health.

- **CEN TC 326 'Natural gas vehicles'**
  - Development of standard for LNG vehicles in use and operation

Monitoring EU funded CNG & LNG projects



2014 Call
Funding: €42 million
Stations: 24 LNG, 5 CNG

2015 Call
Funding: €240 million
Stations: 46 LNG, 3 L-CNG, 26 CNG

2016 Call:
Funding: €160 million
Stations: 38 LNG, 9 L-CNG, 24 CNG

Blending Call April Q1 2018
€1.3 billion

DECARBONISATION

CO_2 emissions: just a question of engine and vehicle efficiency ?

Fighting for engine efficiency

N.L.S. Carnot established the thermal cycle with the highest possible efficiency

J.B. Zeldovich established the reaction kinetic process for Nitrogen oxidation

Courtesy Mr C. Weber – EUCAR Powertrain EG

Thanks to its composition Natural Gas provides best perspectives in terms of energy efficiency increase in ICEs.

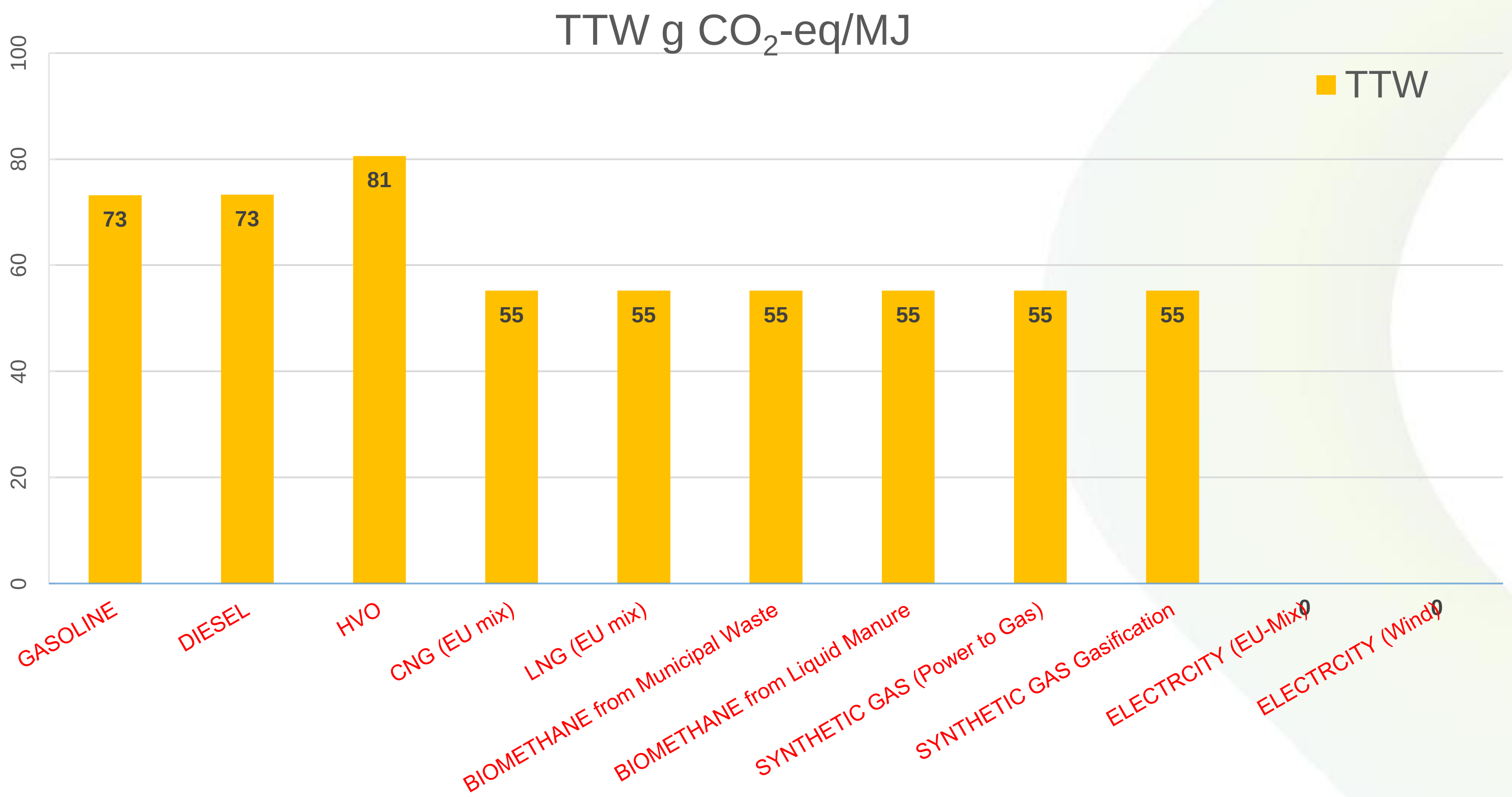
High compression ratio and high boosting rate are allowed thanks to RON equivalent to 130.

And NOx emissions effectively converted through 3-way catalyst.

Nevertheless…

CO_2 emissions comparison

Looking to tailpipe emissions



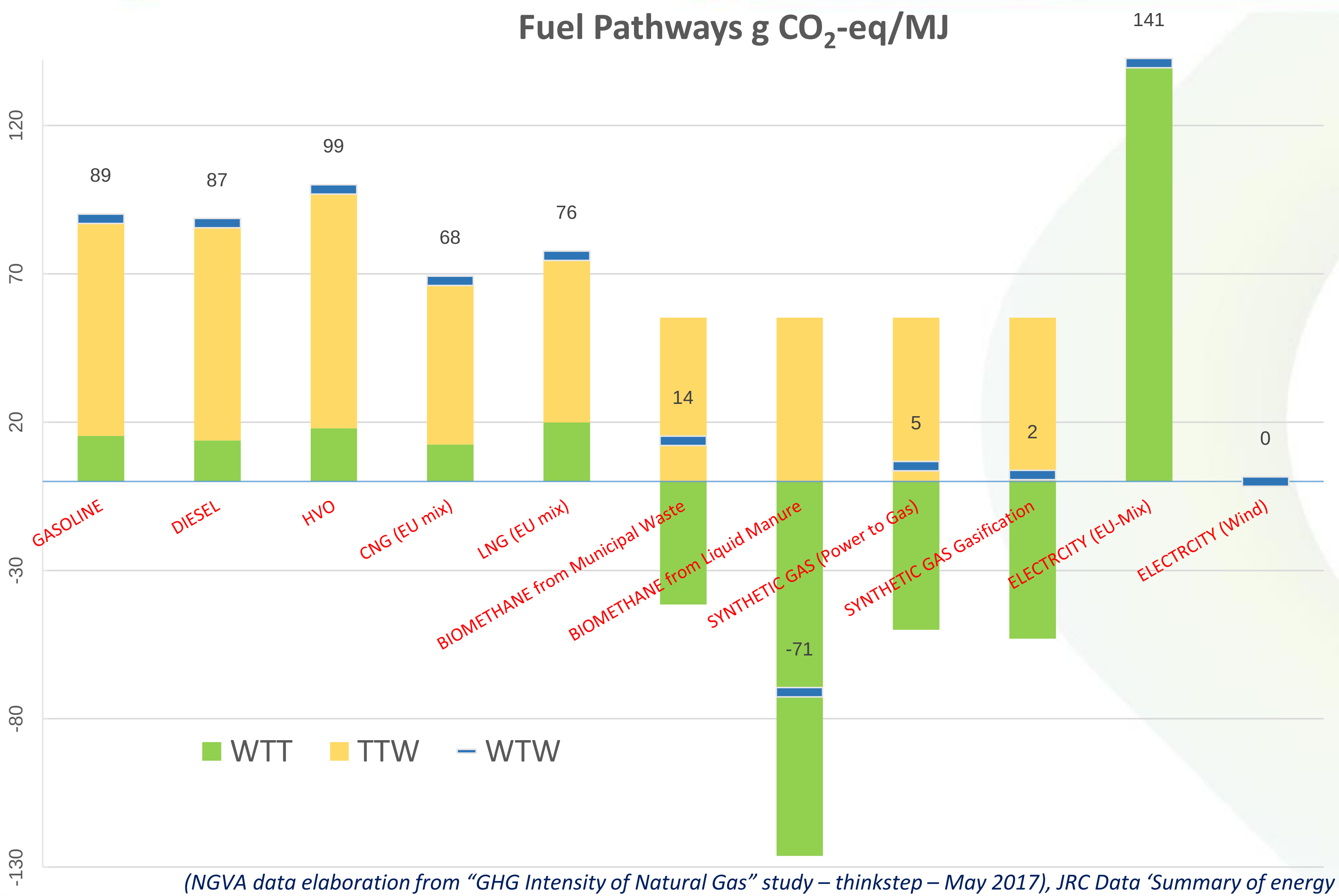
Tailpipe emissions are not able to provide information if CO_2 is generated from fossil or renewable fuel

Of course, BEV result zero emissions

Nevertheless…

(NGVA data elaboration from "GHG Intensity of Natural Gas" study – thinkstep – May 2017), JRC Data 'Summary of energy and GHG balance of individual pathways' WTT April 2014

CO_2 emissions comparison



Renewable gas can provide a significant contribution to decarbonisation

Today's CNG and LNG vehicle technologies are ready to run 100% renewable!

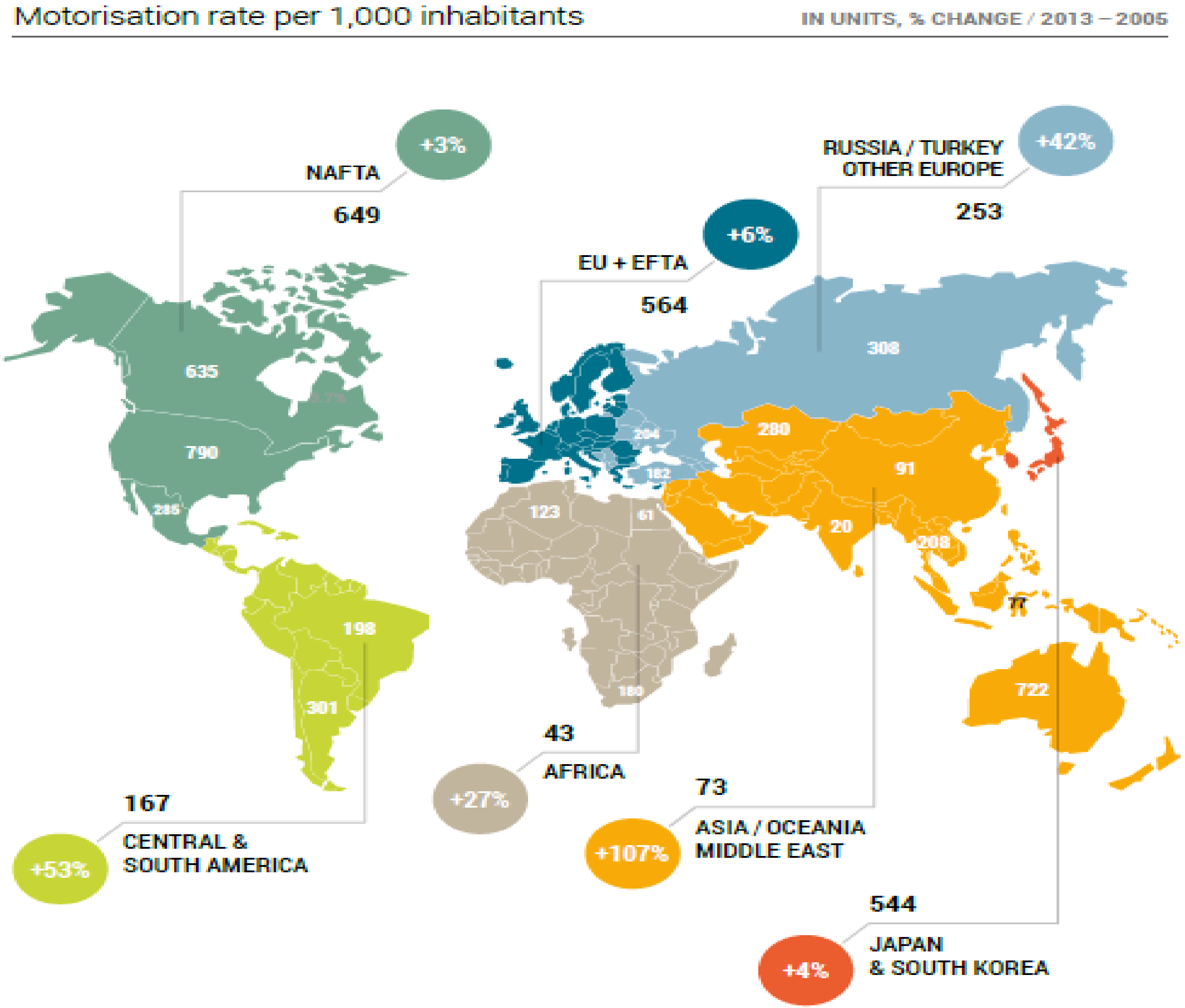
(NGVA data elaboration from "GHG Intensity of Natural Gas" study – thinkstep – May 2017), JRC Data 'Summary of energy and GHG balance of individual pathways' WTT April 2014

Air quality

Beyond CO_2 emissions

Motorization rate worldwide

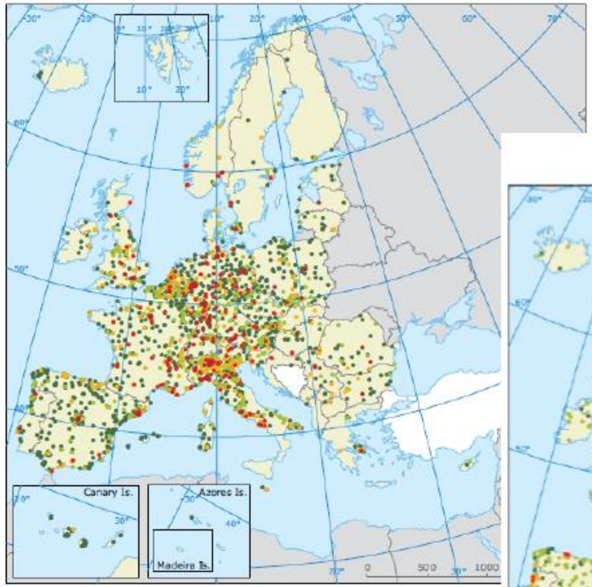
Increase need for individual mobility continuously needs for clean solutions



The air we breath

Despite the evolution of the emissions standard, air pollution is still a major concern

Concentrations of NO_2 in 2013



Premature deaths attributable to $PM_{2.5}$, O_3 and NO_2 exposure in 2012 in 40 European countries and the EU-28

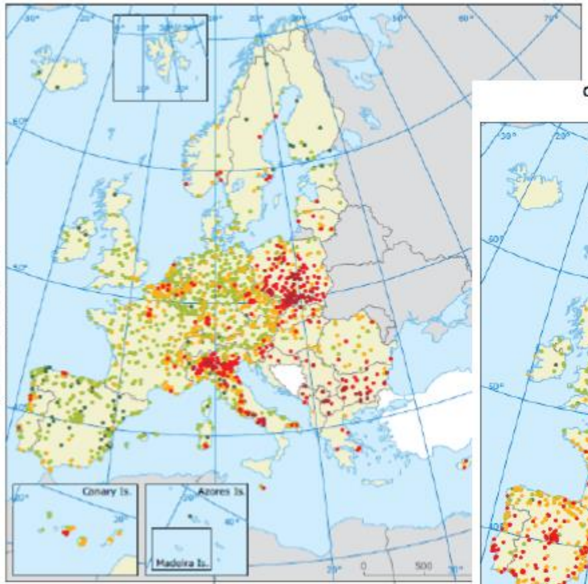
	$PM_{2.5}$	O_3	NO_2
Total ([b])	432 000	17 000	75 000
EU-28 ([b])	403 000	16 000	72 000

Source: EEA Air Quality in Europe 2015

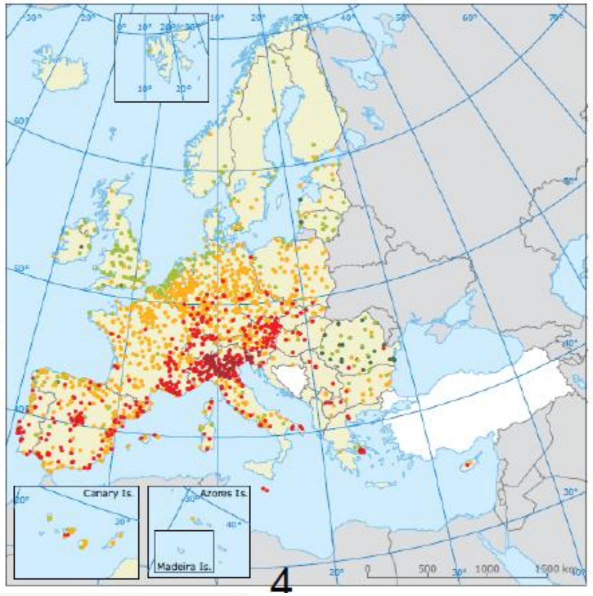
Table 9.1 Years of life lost (YLL) attributable to $PM_{2.5}$, O_3 and NO_2 exposure in 2012 in 40 European countries and the EU-28

Country	$PM_{2.5}$			O_3			NO_2		
	Annual mean	YLL	YLL/10^5 inhabitants	SOMO35	YLL	YLL/10^5 inhabitants	Annual mean	YLL	YLL/10^5 inhabitants
Total ([b])		4 804 000	895		215 000	40		828 000	154
EU-28 ([b])		4 494 000	898		197 000	39		800 000	160

Concentrations of PM_{10} in 2013



Concentrations of O_3 in 2013



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Data source for Passenger Cars


CNG mobility
State-of-the-art technology

NFP70 project
Renewable Methane for Transport and Mobility
Sub-contracting project report 1

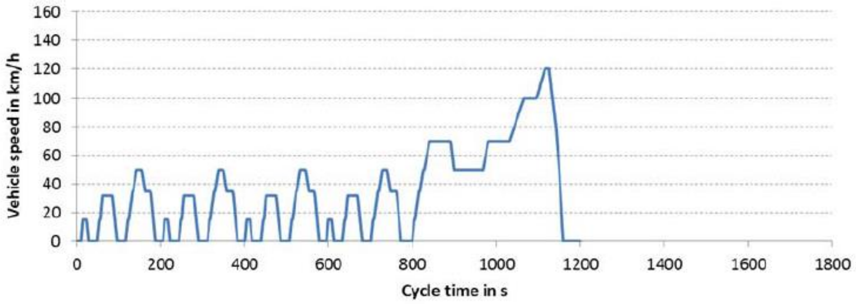
Empa
Swiss Federal Laboratories for Materials Science and Research
Ueberlandstrasse 129
CH-8600 Dübendorf

Automotive Powertrain Technologies Laboratory

Empa
Materials Science and Technology

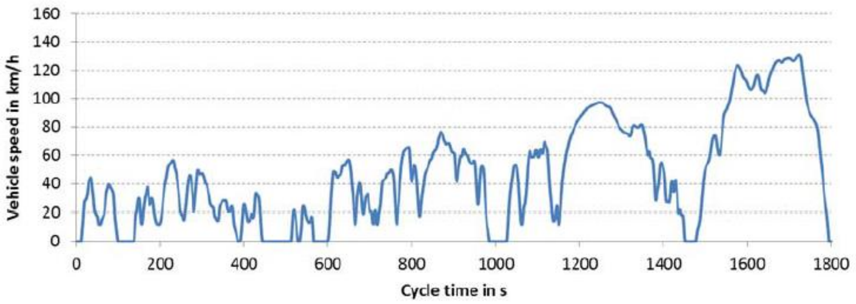
NEDC

Actual mandatory driving cycle



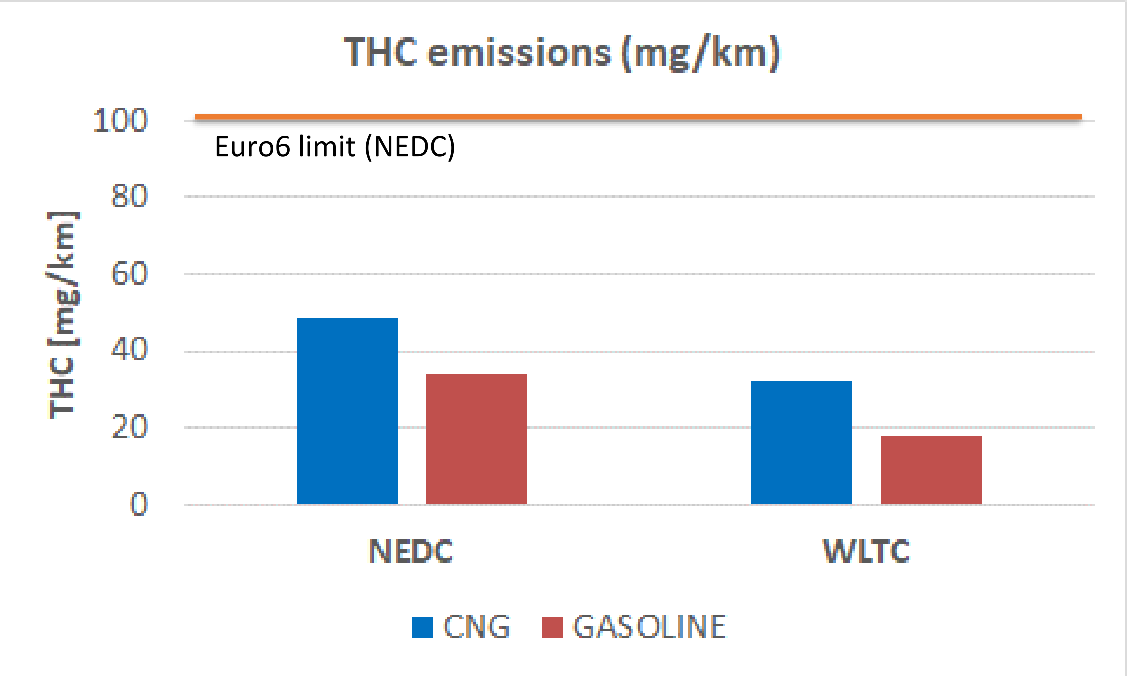
WLTC

New mandatory driving cycle (2017)



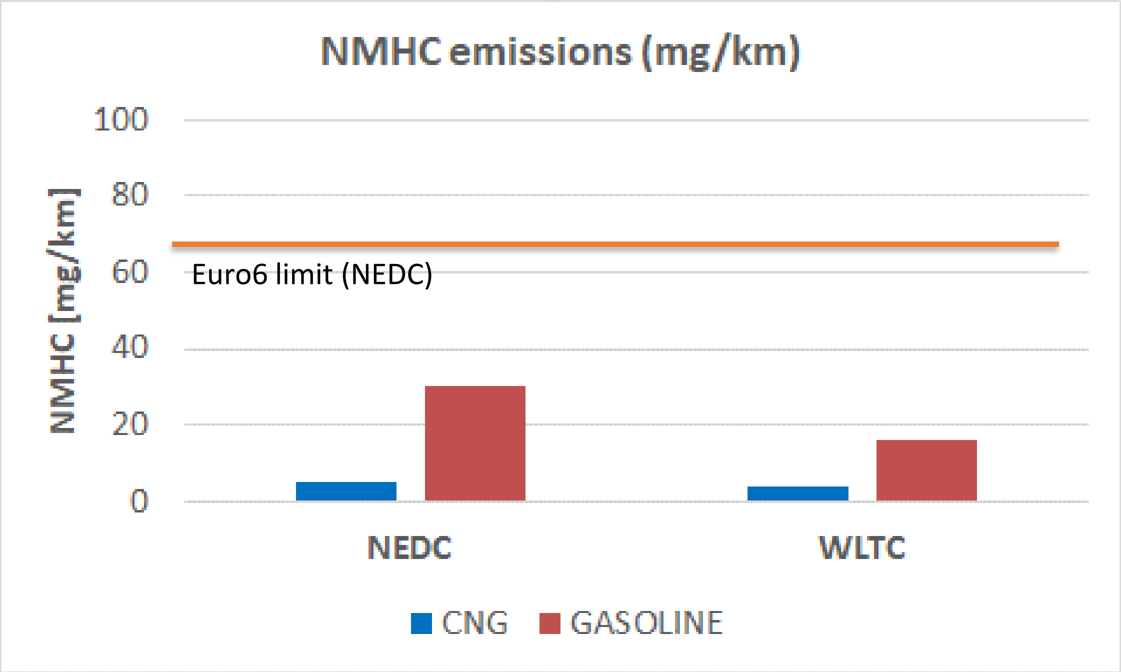
Emissions assessment comparing CNG and gasoline Euro 6b vehicles (same model mid-size segment) under NEDC and new WLTC

Unburned hydrocarbons comparison

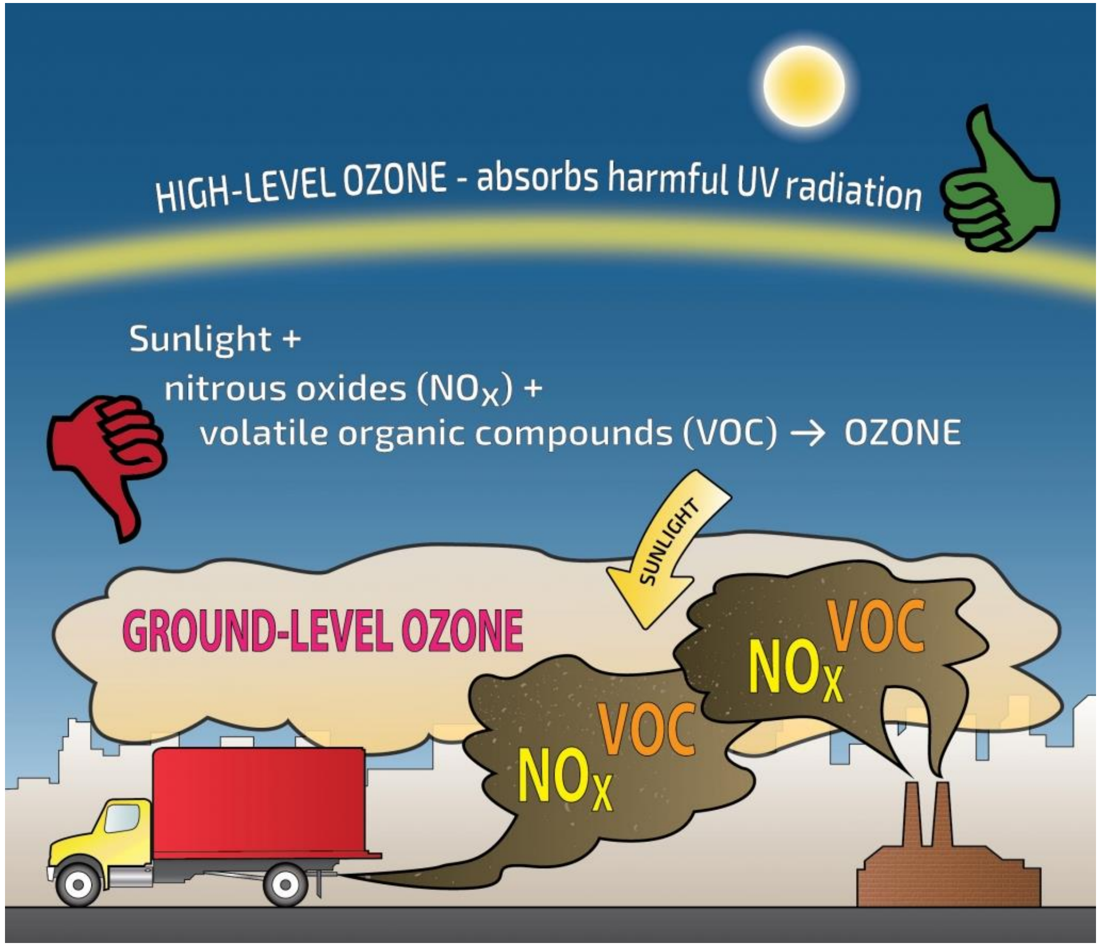


NMHC emissions represent 10% of THC on CNG

10 times less reactivity to ozone formation



NOx and NMHC emissions: why so important

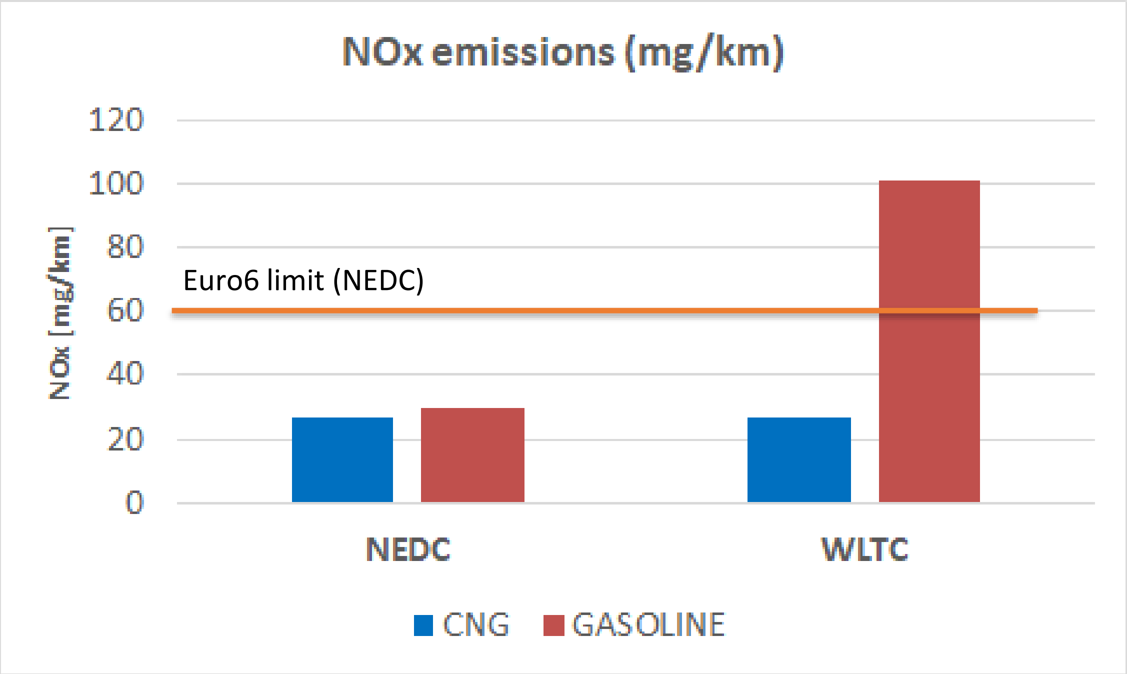


Source : IPCC

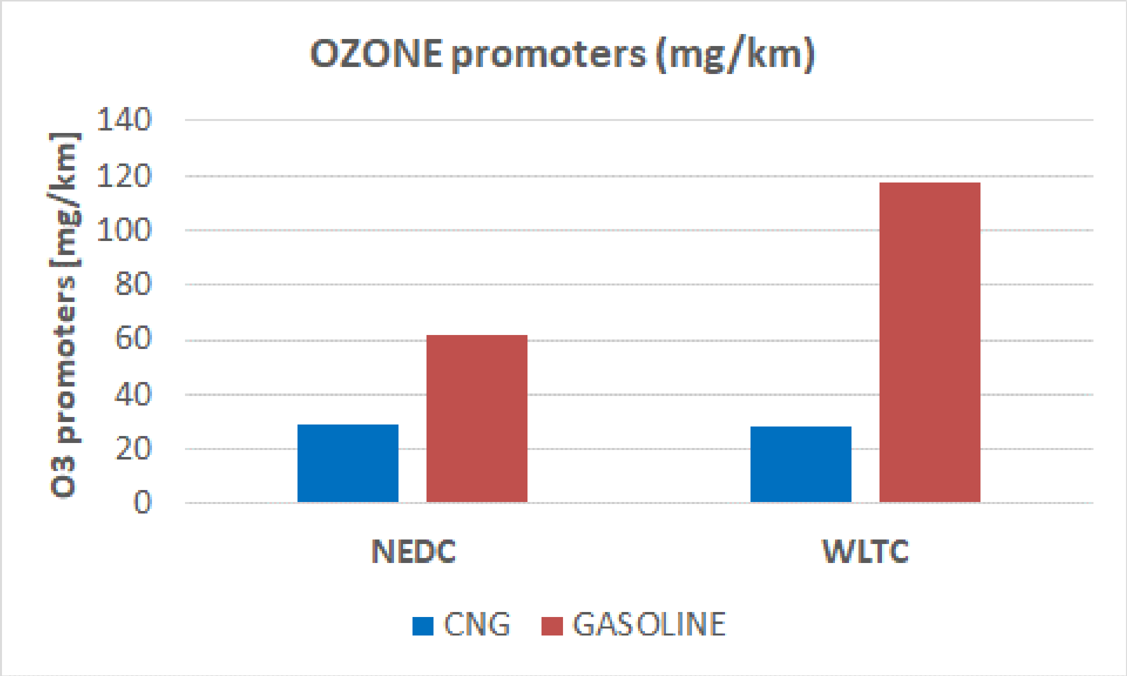
NO_2 in the atmosphere is responsible for the formation of <u>ground-level ozone</u> in combination with non-methanic hydrocarbons and sunlight, causing direct effects on respiratory tract, damage to plants and acidification.

Engine NOx emissions are primarily NO with some NO_2 but even NO is transformed to NO_2 once in the atmosphere.

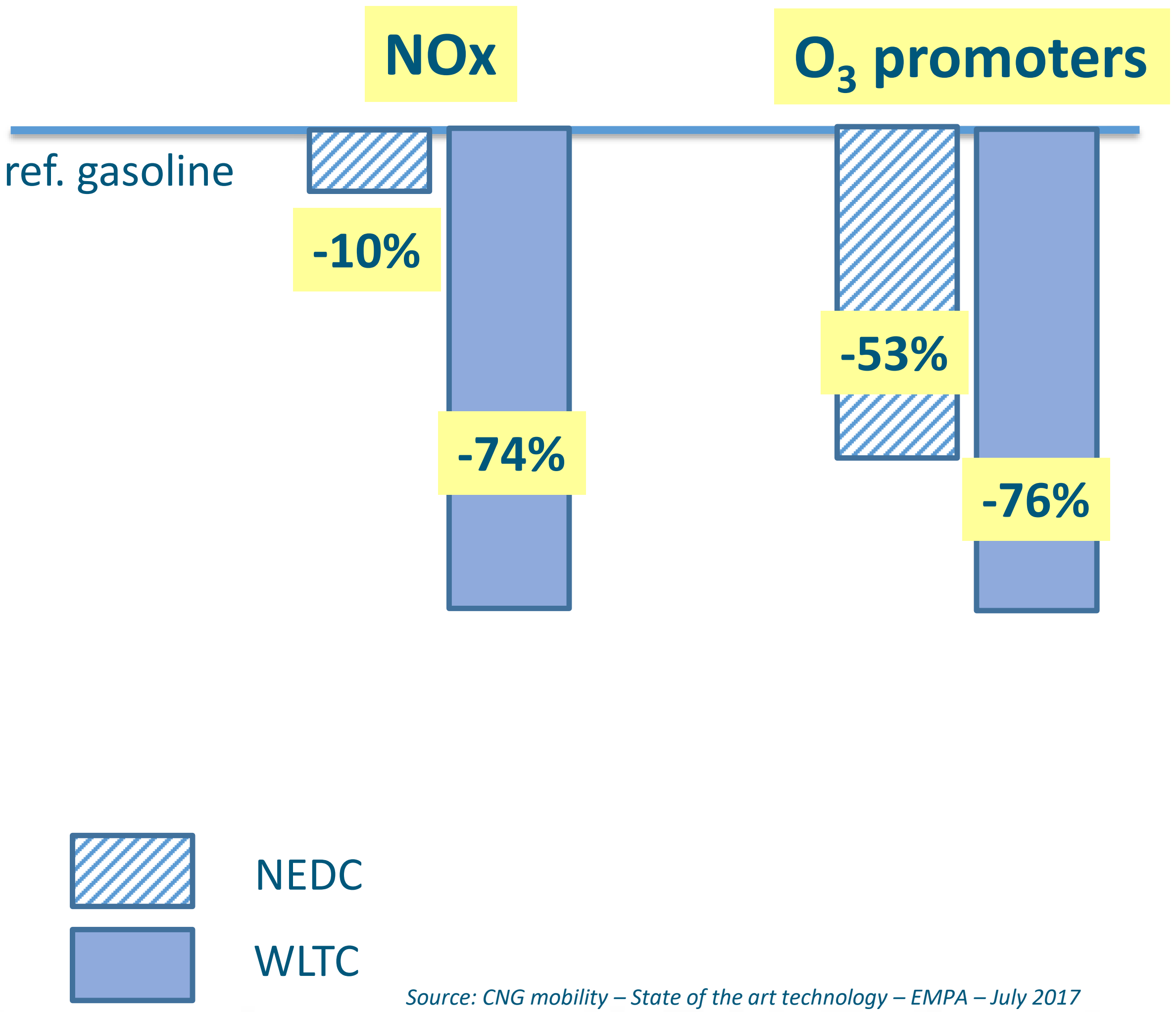
NOx emissions and ozone promoters



OZONE promoters result from the combination of NOx and NMOG emissions



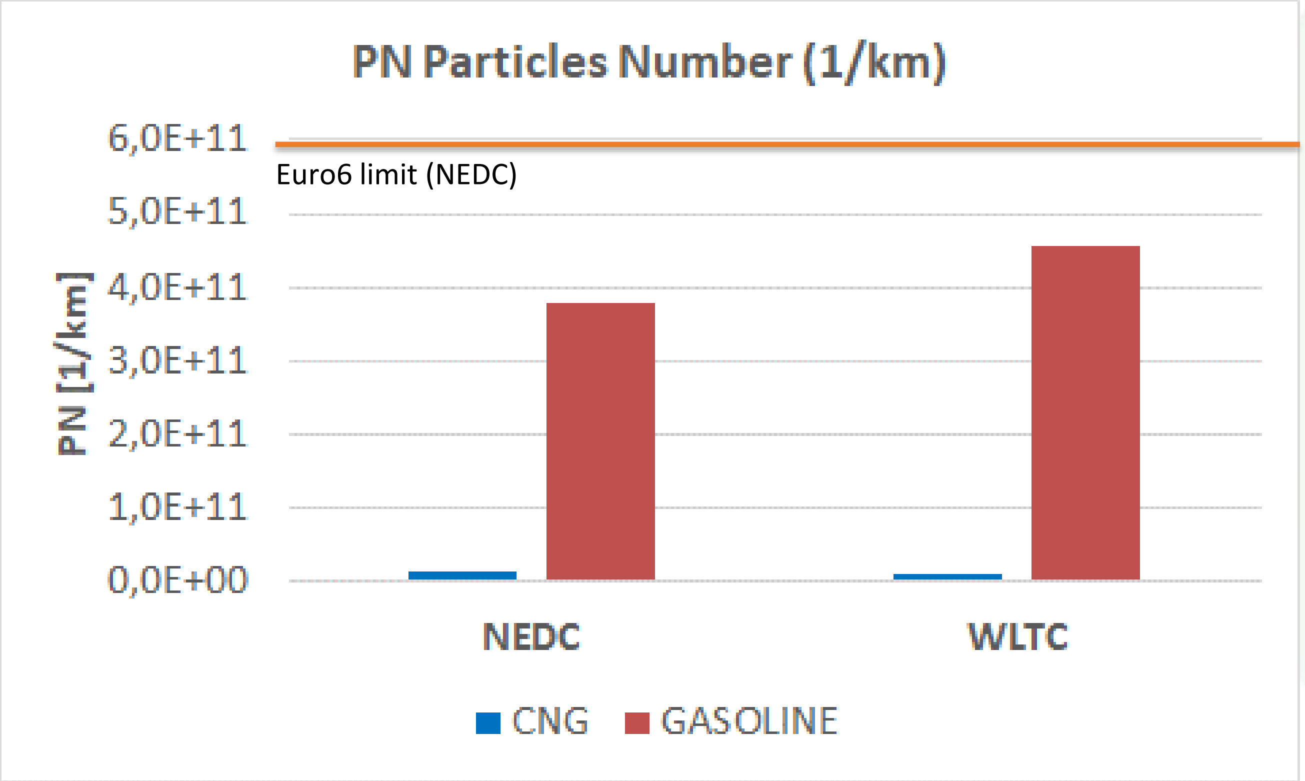
NGV maintain a clear advantage w.r.t. gasoline even under WLTC conditions



Source: CNG mobility – State of the art technology – EMPA – July 2017

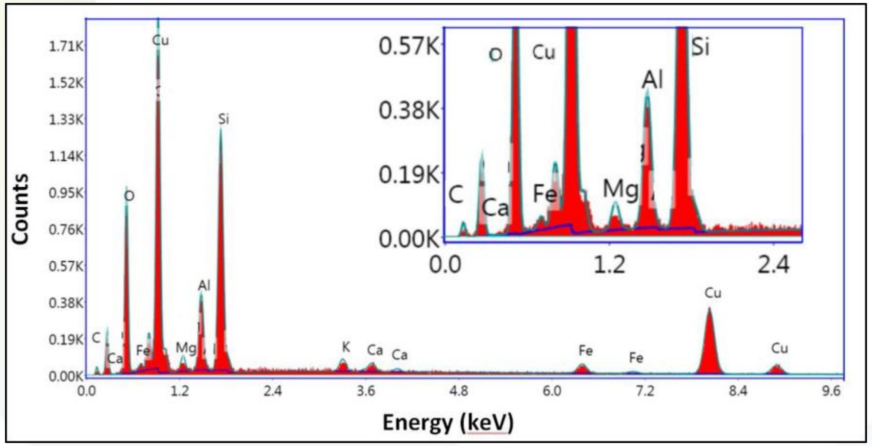
CNG reveals a robust solution to drastically reduce NOx when moving towards real driving conditions (WLTC) ensuring the lowest level of Ozone promoters formation

A particulate free combustion

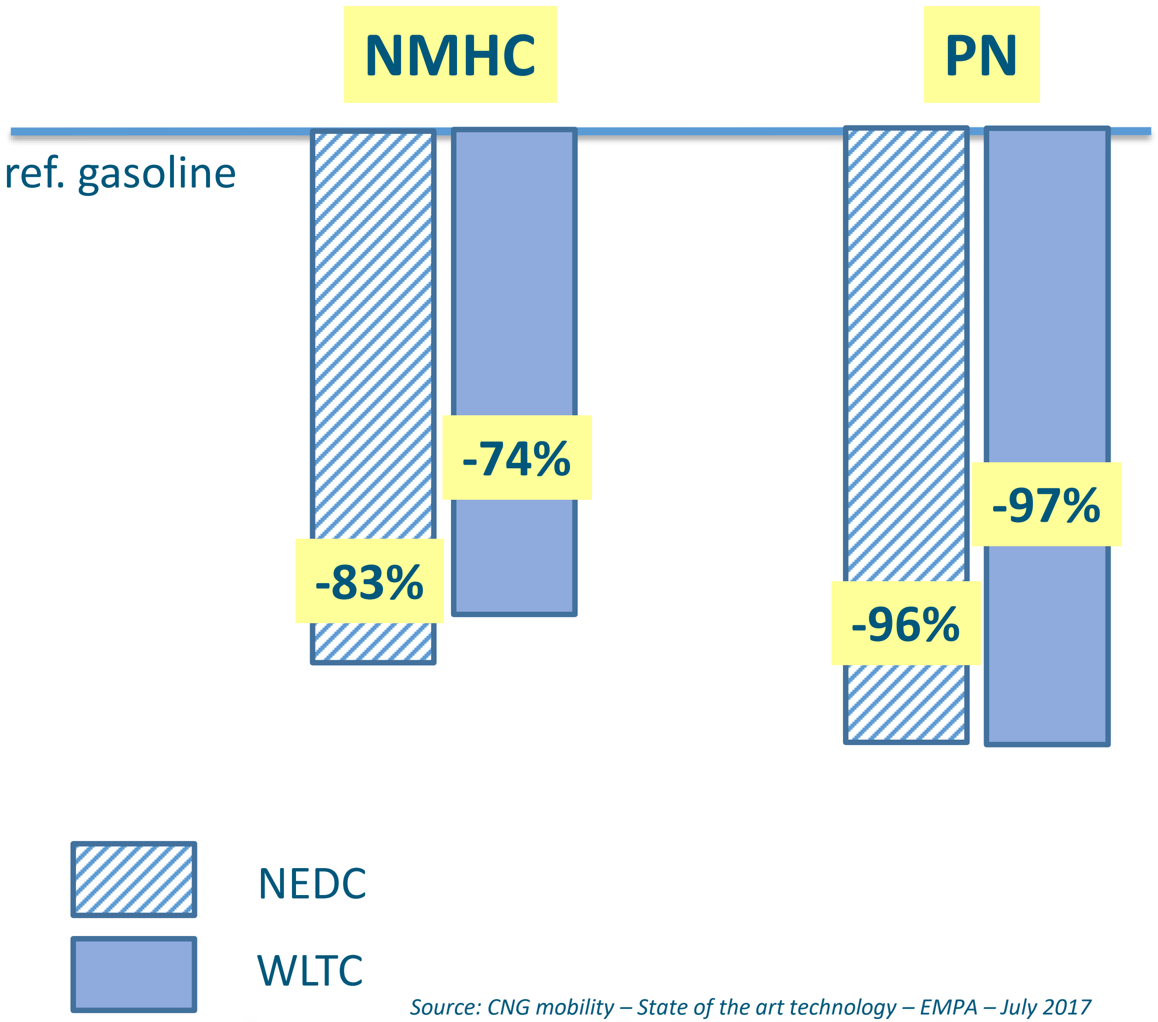


Natural gas ensures the lowest level in terms of particle emissions

Particles within NG engines combustion are mainly generated from lubricant additives



EDS – Energy Dispersion Spectroscopy – analysis of exhaust particles from CNG engine
SAE Paper – 2017-01-0778

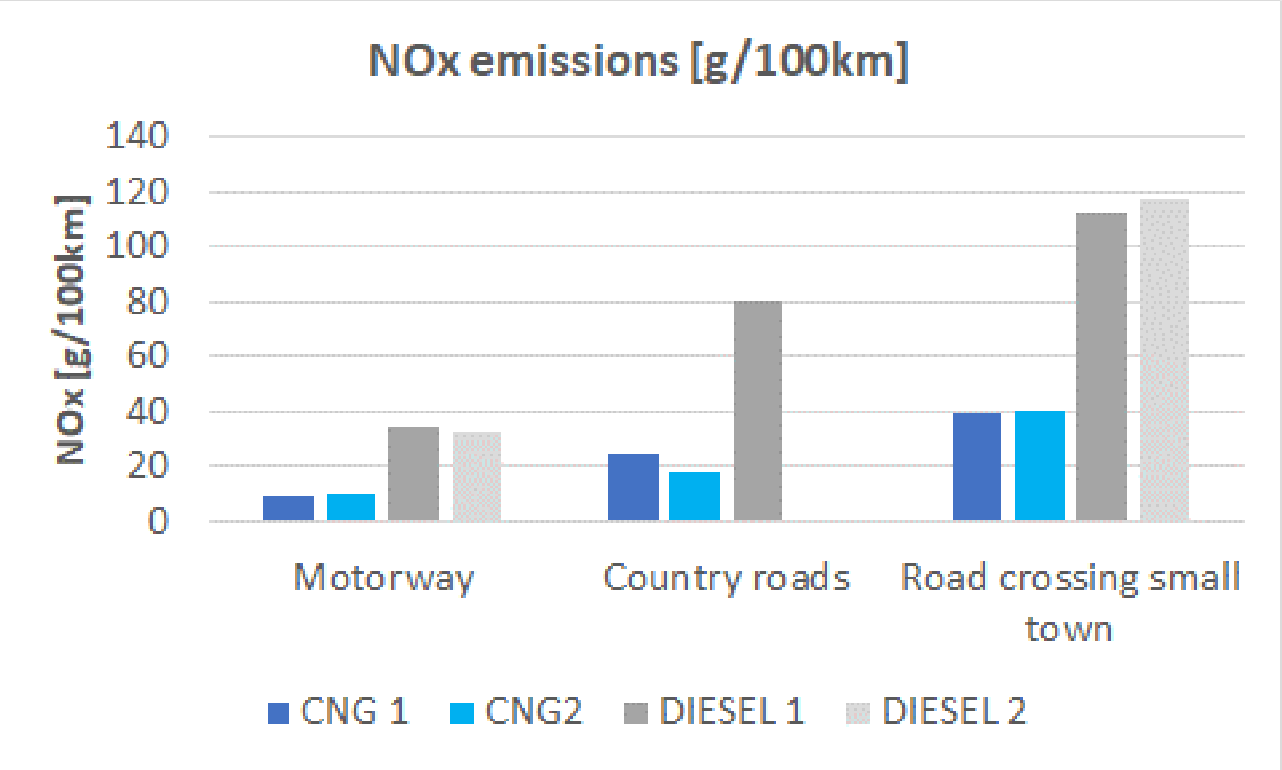


CNG provides consistent benefits in terms of NMHC (Non Methanic HydroCarbons) and PN (Particle Number) reduction towards gasoline even when moving from NEDC to WLTC

Source: CNG mobility – State of the art technology – EMPA – July 2017

Comparing NOx emissions vs Diesel – HD applications

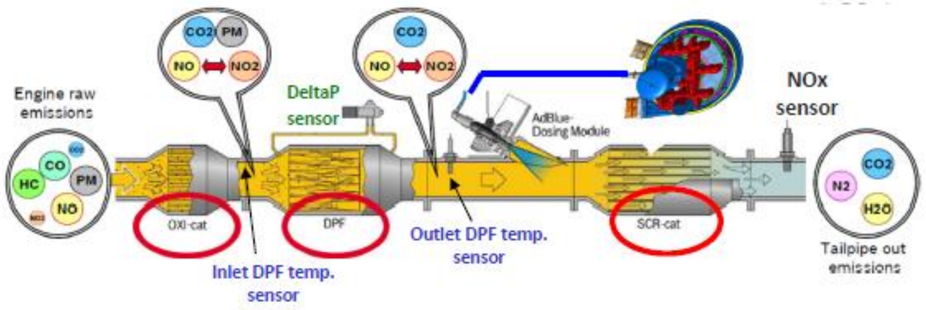
On road emissions measurement (PEMS) on 44 tons EURO VI CNG and DIESEL trucks fleet over 1 year testing programme



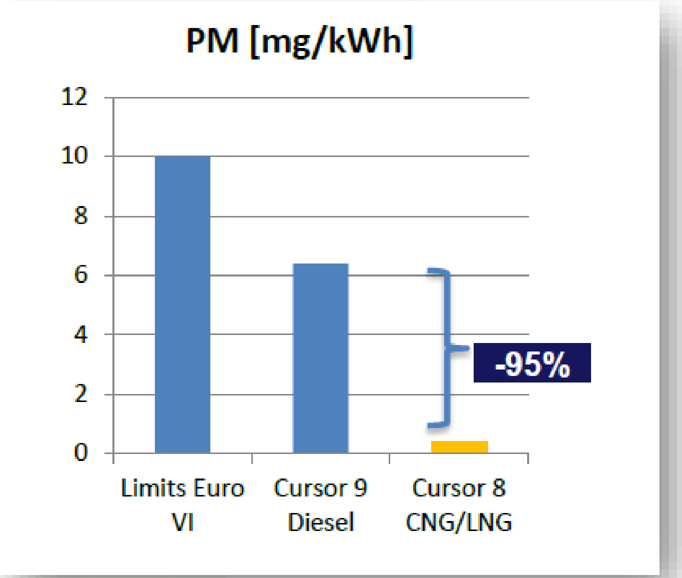
NOx emissions are lower with CNG all over the testing conditions

Particulate emissions – HD applications

3-way catalyst for CNG S.I. stoichiometric engine



DOC + DPF + SCR system for DIESEL engine

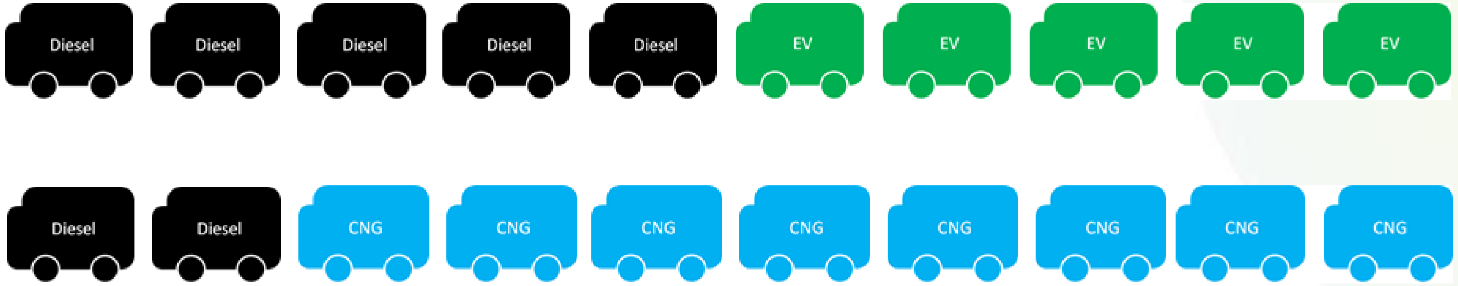


Natural gas engines ensure the lowest level in terms of particle emissions thanks to a soot free combustion, no need for a complex after-treatment system

Environmental benefit from fleet renewal at same cost

	DIESEL Euro VI	CNG Euro VI	EV
Vehicle cost	100	115	182
NOx	100	30	0
PM	100	5	0

Source: JRC GPP-TR_D2_0517



500 (NOx) + 500 (PM)

440 (NOx) + 240 (PM)

- 32% with CNG

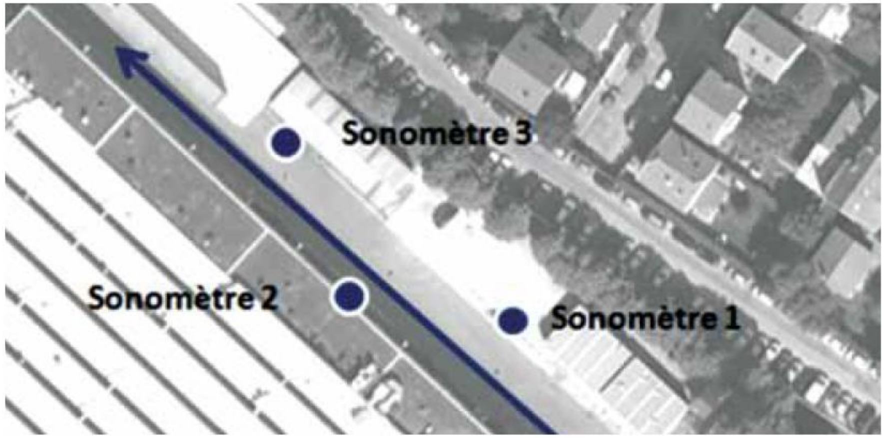
Natural gas : close-to-zero emissions + affordability

Pollution means also noise reduction

Caractérisation des niveaux de bruit des poids lourds : comparatif Diesel/GNV

ACOUplus Acoustique & Environnement

November 2016



	Diesel Moyenne dB(A)	GNV Moyenne dB(A)	Différence dB(A)
Sonomètre 1	68.5	63.6	4.9
Sonomètre 2	71.7	68.5	3.2
Sonomètre 3	72.4	69.3	3.1

Sound level measurement at 10 km/h from equivalent CNG and Diesel truck (from same manufacturer)

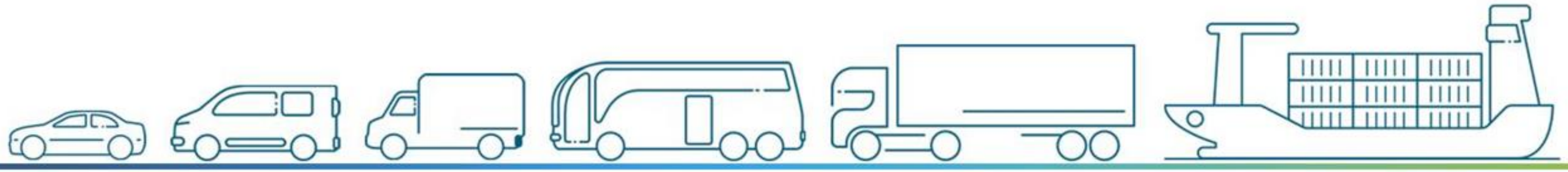
Natural gas ensures lower level of noise (-3 dB(A) means halving noise level)

Ideal for urban overnight operations !

NGVA

Europe

for sustainable mobility



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