POTENTIALS OF GAS MOBILITY IN ROAD TRANSPORT

POTENZIALE DER GAS-MOBILITÄT IM KRAFTVERKEHR

Prepared for

BDEW-Fachkongress
Treffpunkt Netze 2016

Berlin, 2016-03-02

Christof Schernus, RD, Knut Habermann, BGP, Kontakt: schernus@fev.com

Credits/Ackowledgement

THIS PRESENTATION USES CONTENT ELABORATED IN PROJECTS FUNDED BY THE EUROPEAN COMMISSION

- **GasOn** - Gas-Only Internal Combustion Engines
  - Project reference: 652816
  - Funded under H2020-EU.3.4.
- **LNG** Blue Corridors - Demonstration of heavy duty vehicles running with liquefied methane
  - Project reference: 321592
  - Funded under FP7-TRANSPORT

- Further acknowledgements are due to our partners in the GasOn project (www.gason.eu) and to colleagues at FEV
  - Kirsten Hentschel
  - Johannes Scharf
  - Matthias Thewes
  - Tolga Uhlmann

Footnote

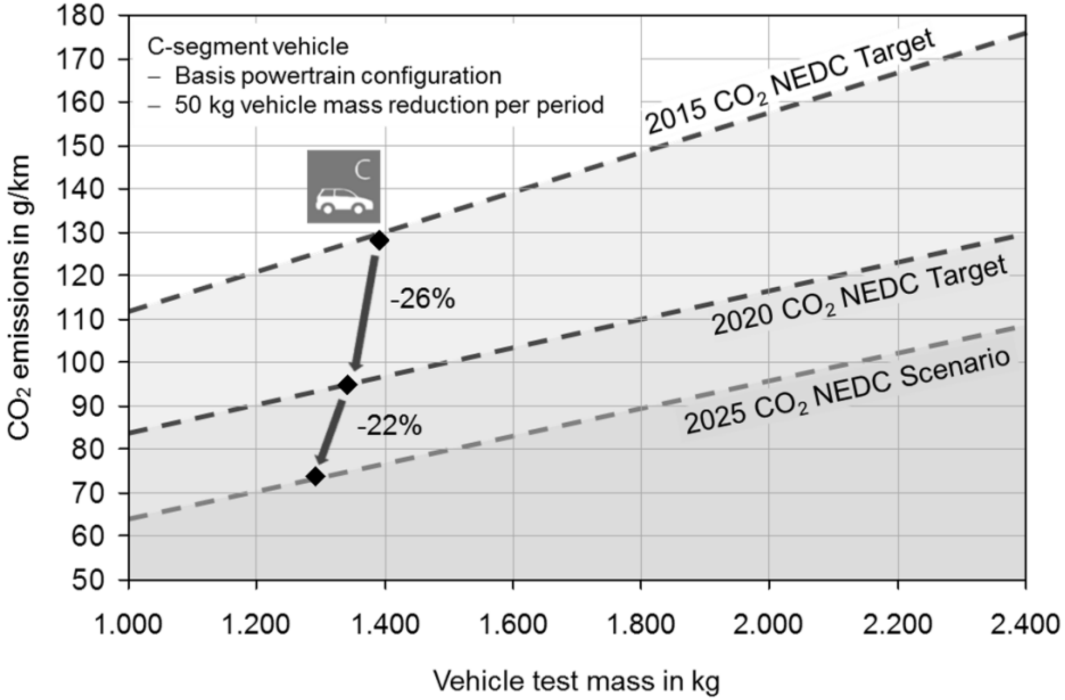
Agenda

- Boundary conditions and technology drivers
- Customer and OEM benefits
- NG vehicle market
- Engine technology – current and future
- Methane fuels – status and requirements
- Summary & outlook

Footnote

Future CO2 emission restrictions are strongly challenging to car makers. They must create not only technology – but also customer acceptance.

FLEET CO_2 EMISSONS MUST DECREASE BY ALMOST 50% IN 10 YEARS



European CO2-emission fleet targets

- Current: 130 g_{CO2}/km
- 2020: 95 g_{CO2}/km (~ -26%)
- 2025: 68-78 g_{CO2}/km (~ -21%) under discussion

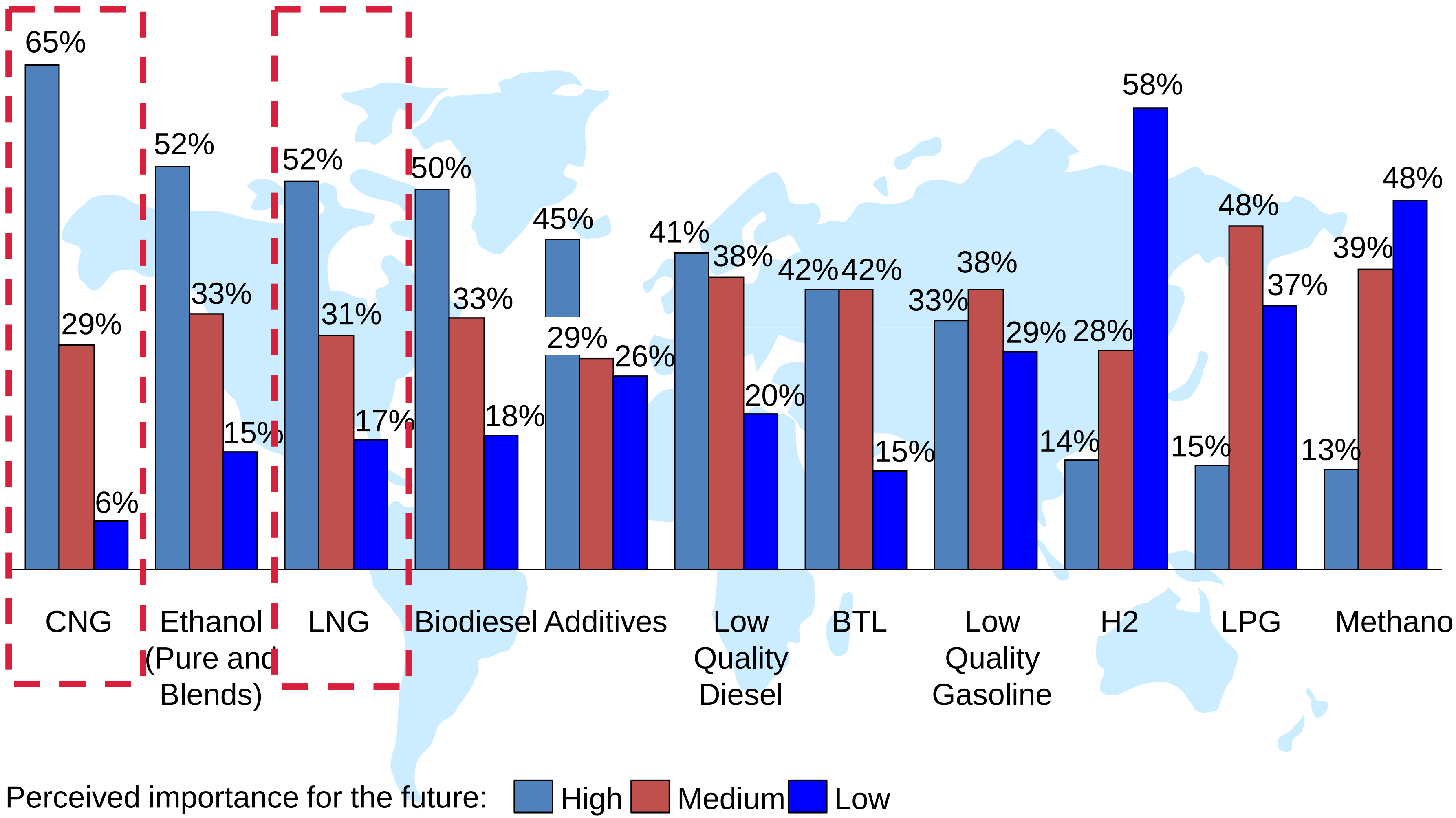
Amendments, incentives, and concessions

- Phase-in: Target of 95 g/km through 95% in 2020, 100% from 2021
- Super credits: Vehicles w/ < 50 g/km with factor > 1 lowering the average fleet CO_2 value
- Eco-innovations: Technologies effective under real driving conditions but not in NEDC (≤ 7 g/km p.a.)
- Pooling: Different OEM cooperate to jointly achieve the CO2 target value
- Small volume manufacturers: Fixed 25% (45%) reduction vs. 2007 (2020) for OEM w/ < 300k cars p.a.

Source: European Commission 2014, FEV Aachen Colloquium 2015

Natural gas & biofuels are perceived to be the most important fuels for the short & medium term future – H2 & Methanol are not expected to play a role

PERCEIVED FUTURE IMPORTANCE OF DIFFERENT FUELS (FVV STUDY 2012)

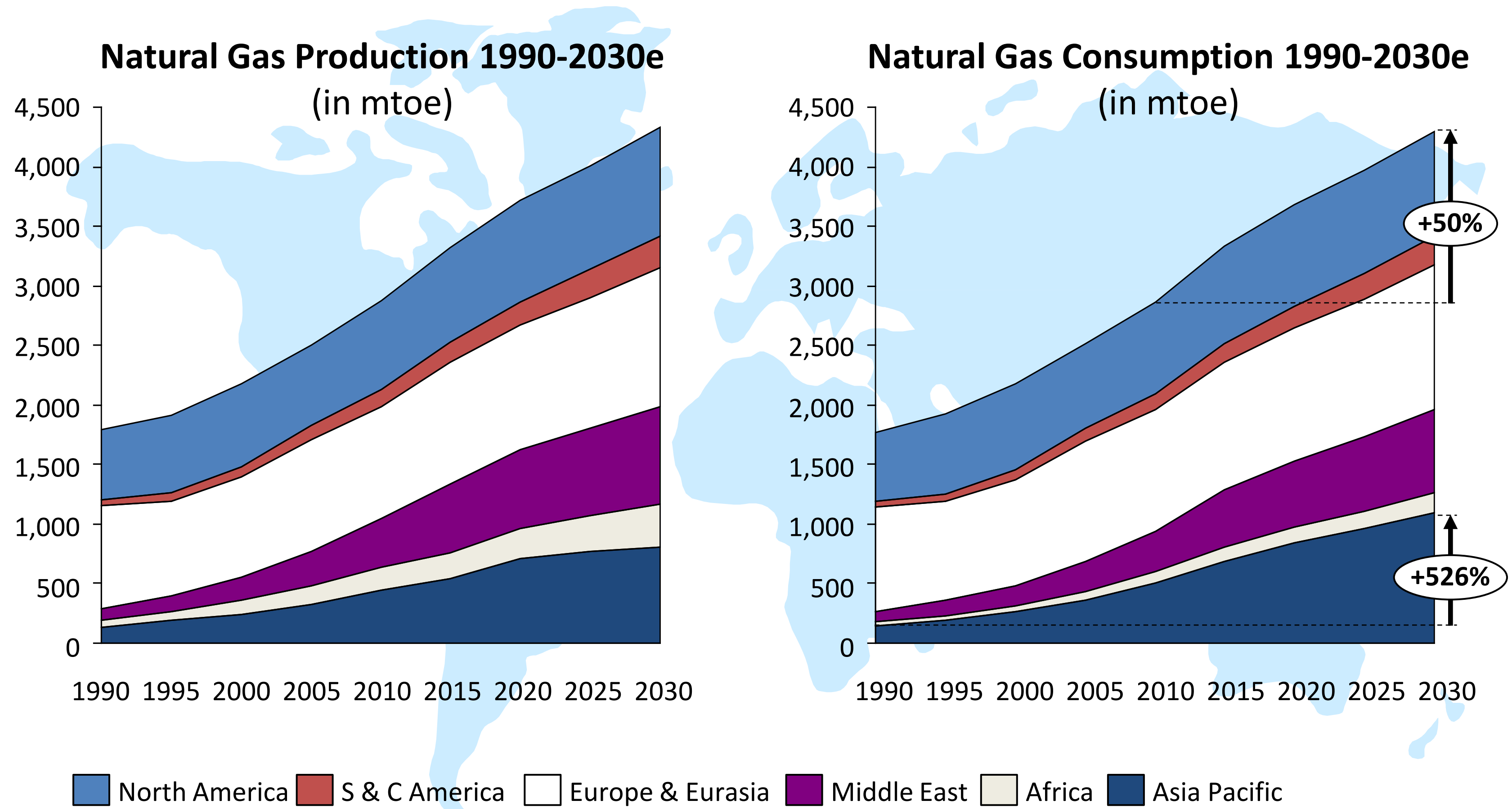


Source: FVV Study (2012), FEV analysis

Footnote

Natural gas has been a success story and the rise is expected to continue with an average 2.1% growth per year for the next two decades

NATURAL GAS PRODUCTION AND CONSUMPTION – OUTLOOK TO 2030



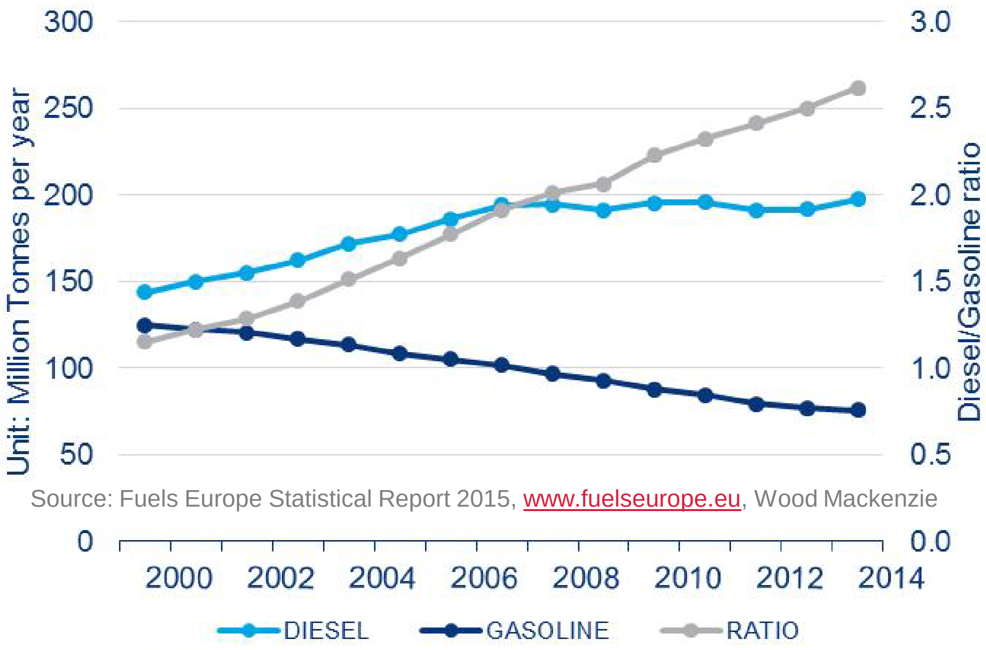
- Overall increase of consumption of 50% in 20 years
- Growth by a factor >5 in Asia from 1990 to 2030

Source: BP Energy Outlook 2030 (published 2012)

Footnote

Decarbonisation of Road Transport is a major challenge as it represents more than 70% of the energy used by all transport modes[1].

CONSEQUENCES OF REPLACING FOSSIL LIQUID FUELS FOR TRANSPORT BY CNG



Overall fuel consumption in EU in 2012:[2]

- NG: 400 Mtoe/y
- Oil: 611 Mtoe/y

Thereof 280 Mtoe/y oil (i.e. ~ 46%) for road transport:

- diesel: ~200 Mtoe/y
- petrol: ~80 Mtoe/y

Oil energy consumption for road transport equals to 70% of total NG energy consumption in EU

Replacing fossil liquid fuels provides the potential to

- Reducing CO2 emissions in in g/km by 22% only by the modified H/C ratio without exploiting increased engine efficiency
- Increasing the market volume for NG by up to 70%

Sources: ,

[1] http://www.ngva.eu/eu-policy-and-ngvs

[2] "Methane Fuels: European Automotive Fuel Quality and Standardization Requirements", Gas Powered Vehicles Conference Stuttgart, October 21st, 2015

Agenda

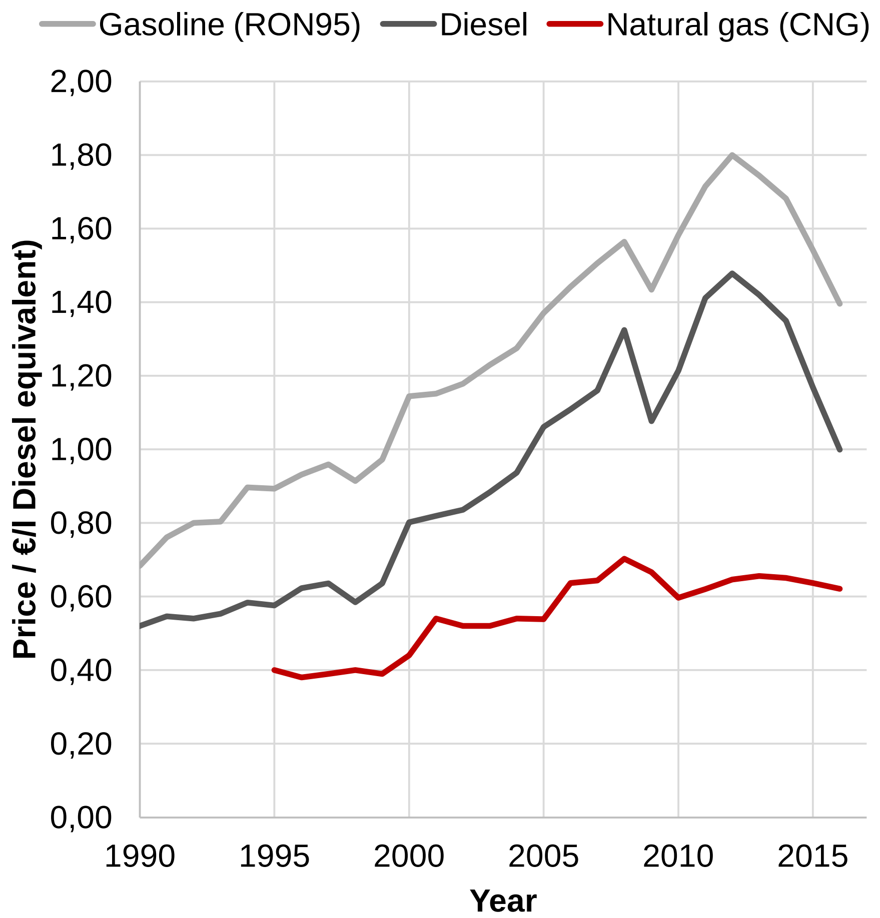
- Boundary conditions and technology drivers
- Customer and OEM benefits
- NG vehicle market
- Engine technology – current and future
- Methane fuels – status and requirements
- Summary & outlook

Footnote

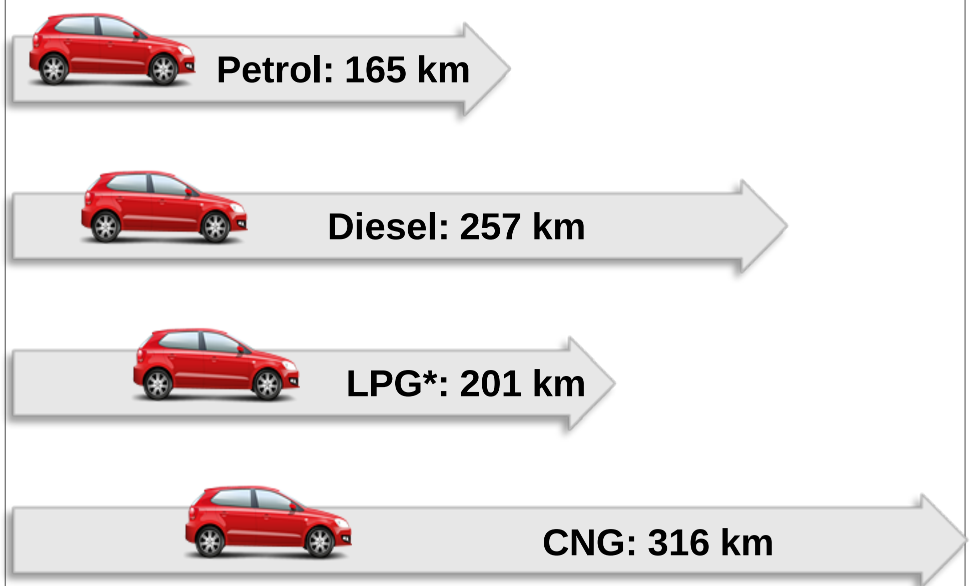
Natural gas is on a like-for-like basis a cheaper fuel and allows about double the mileage than petrol even after the recent significant drop of liquid fuel prices

NATURAL GAS IN EUROPE – THE ECONOMICS OF CHEAPER TRANSPORTATION

Development of Retail Pump Prices in Germany



How many kilometers can you drive with €10?



based on average fuel consumption and range of VW Golf VII, or *Golf VI: Bifuel, resp.

Footnote

As an interim summary, operating vehicles on (C)NG offers significant benefits to both vehicle users and car makers

MOTIVATION FOR PUSHING CNG IN ROAD TRANSPORT

Lowering fleet emissions

- One of the main reasons is the EU-legislation to restrict CO2-emission
- Of all fossil based fuels, CNG has the greatest potential for reducing GHG*
- Incorporation of biogas or P2G leads to further significant reduction

Possible market growth

- Due to the cheap technology, OEM are able to offer fuel efficient vehicles for low prices, making CNG vehicles an attractive product while still earning money
- Early adapters have the chance to gain new market shares and a competitive advantage

Green image

- Low CO2 emissions has become a growing need for customers (taxation), methane burns soot-free – CNG offers the opportunity to improve the brands image
- By offering affordable “green vehicles”, customers short-term TCO benefits are significantly higher than for BEV

*: GHG: Green House Gas

Source: NGVA, Center of Automotive Research

Footnote

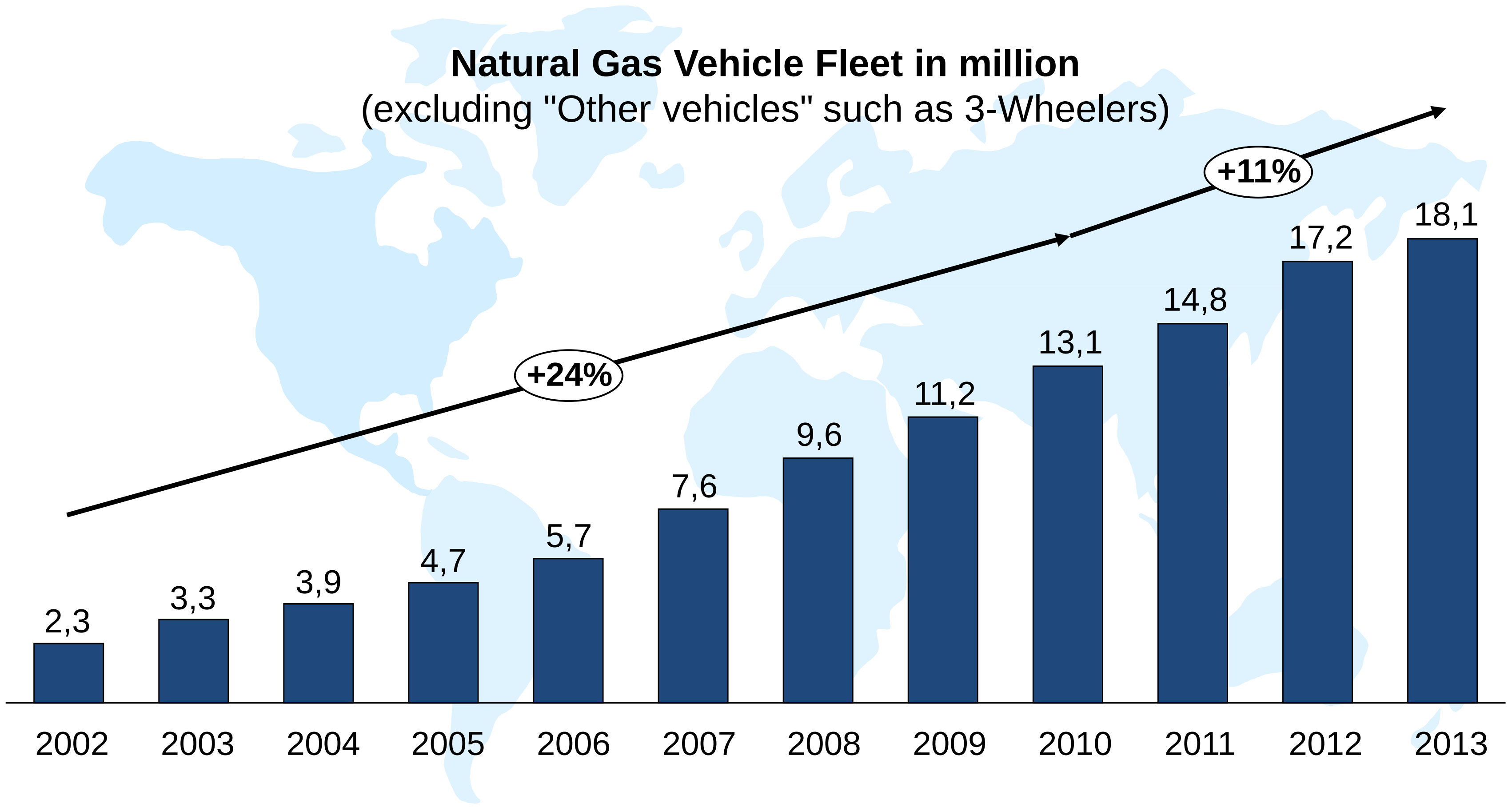
Agenda

- Boundary conditions and technology drivers
- Customer and OEM benefits
- NG vehicle market
- Engine technology – current and future
- Methane fuels – status and requirements
- Summary & outlook

Footnote

Over the past decade the global natural gas vehicle fleet has expanded at a two-digit growth rate

HISTORIC DEVELOPMENT OF WORLD NG VEHICLE FLEET (UPDATE 1/2014)



Source: NGV.com (Number 83, January 2014 report)

Footnote

The use of natural gas in commercial vehicle applications needs to be supported by new infrastructures, e.g on-highway LNG fueling stations

USA AND EUROPE HAVE LAUNCHED PROJECTS TO INSTALL CORRIDORS FOR LNG FUELED FREIGHT TRANSPORT

America‘s Natural Gas Highway

LNG Truck Fueling coast-to-coast and border-to-border

Europe’s LNG Blue Corridors

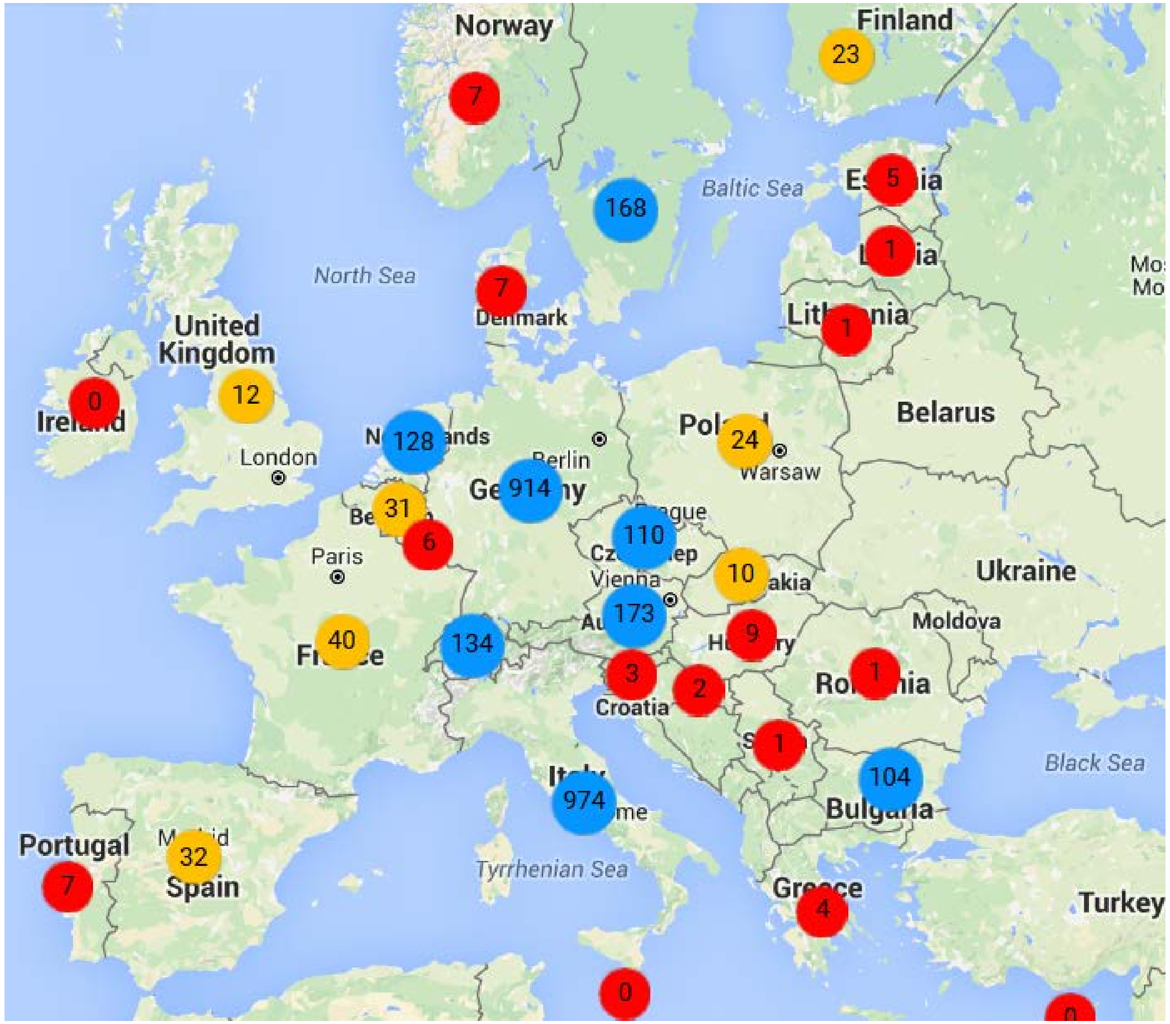
LNG Truck Fueling on main cross-national transport routes

Source: http://www.cleanenergyfuels.com, http://www.lngbluecorridors.eu

Footnote

For individual transport, the coverage of CNG fuel stations is more of concern to accept a new technology

UNEVEN AVAILABILITY OF CNG FUEL STATION THROUGHOUT EUROPE



- Highest numbers of CNG stations in I and D, but
  - only congested urban areas with better coverage, e.g. 10 in Munich, 6 in Berlin
  - large gaps in rural areas
- D, A, CH, I, NL with approx. 18-22 km linear distance between CNG stations
- Desert zones in F, ES, PL, …

Reasons for slow acceptance

- Irrational fears of gas
- Reluctance to innovation
- Sparse fuel station infrastructure

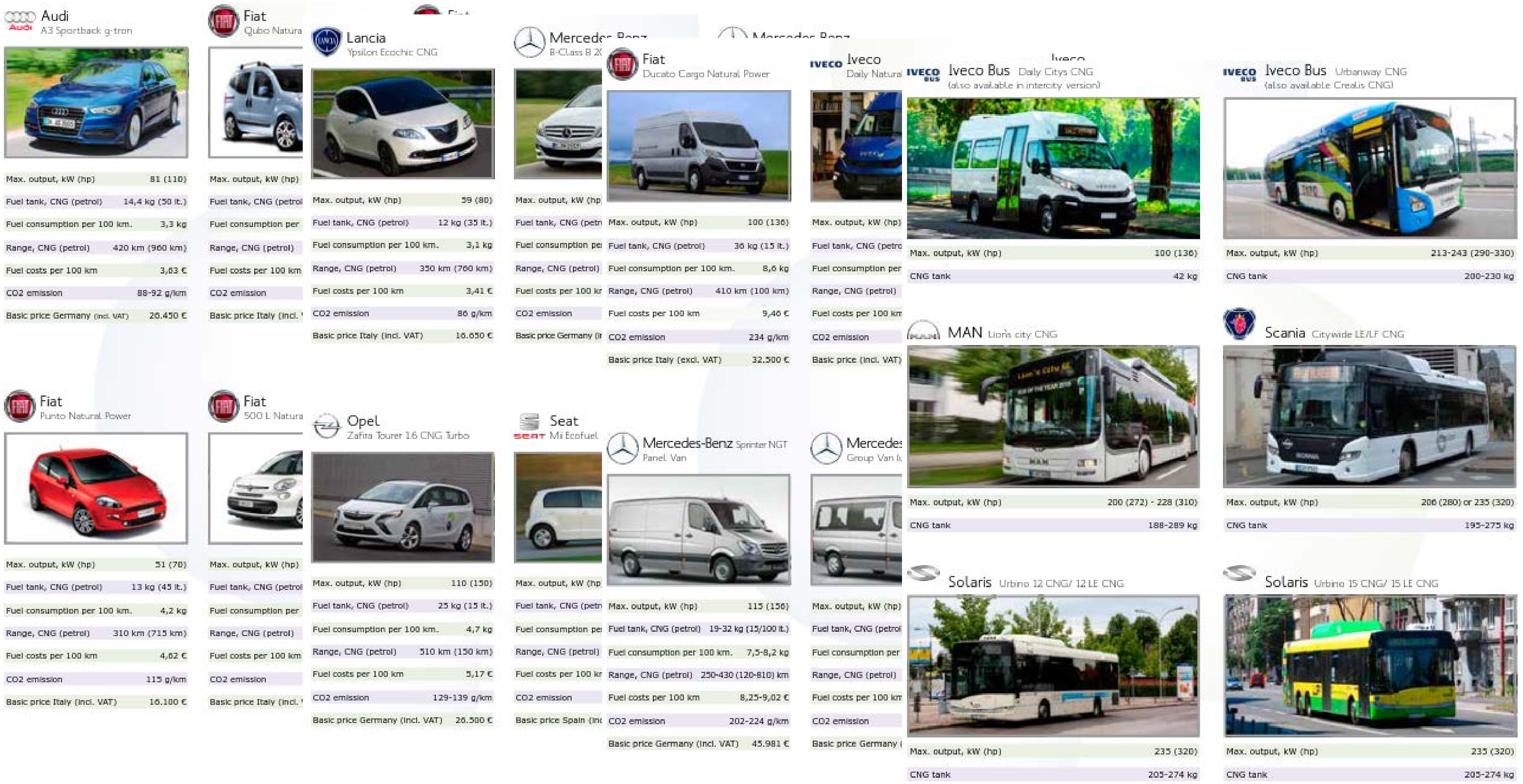
Visibility and density of fuel stations must increase!

Source: http://www.ngva.eu/get-directions

Footnote

There are more than 50 NG vehicles commercially available ranging from compact over full size car up to long haul trucks and buses

A CATALOGUE IS KEPT UP TO DATE AT NGVA'S WEB SITE



Source: http://www.ngva.eu/ng-vehicle-catalogue

Footnote

Agenda

- Boundary conditions and technology drivers
- Customer and OEM benefits
- NG vehicle market
- Engine technology – current and future
- Methane fuels – status and requirements
- Summary & outlook

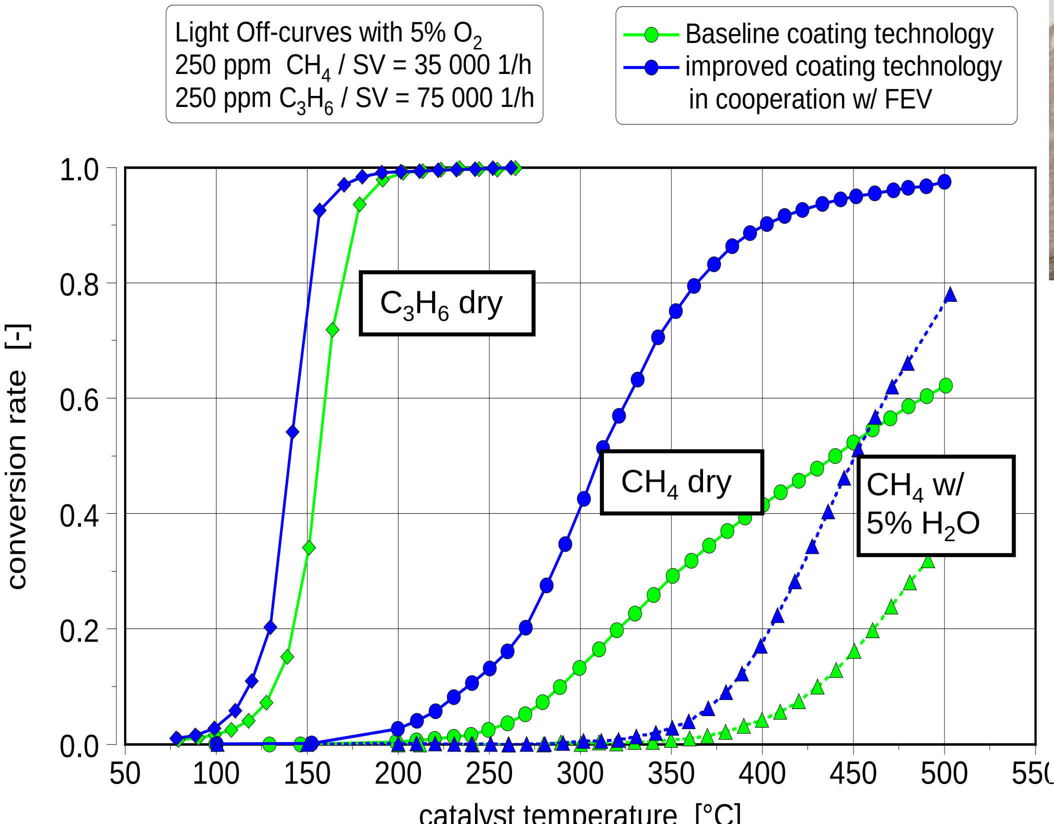
Footnote

Methane combustion provides a number of perfect solutions – but poses also challenges to be tackled

Opportunities	Challenges
☺ ~22 % CO_2 emission reduction (at constant efficiency) ☺ Customer fuel cost savings of up to 50% (at constant efficiency) ☺ High RON (usually RON > 120, Methane Number > 70) allows higher compression ratio ☺ PM / PN conformity for EU6 ☺ No fuel refinery needed	- Filling station infrastructure - Reduced range due to lower energy density of CNG - Engine hardware has to be adapted & additional components required (Bi-Fuel) ⇒ higher costs - 15 % power reduction for NA engines (theoretical value) (→ volumetric efficiency, λ=1) - Almost no component protection via enrichment possible - High thermal load to the DI gasoline injector during gas usage - Less thermal exhaust gas energy ⇒ Turbo lag - Increased demands to the ignition system (especially for lean burn) - Additional precious metals in catalytic converter to get rid of unburnt methane and compensate bad light off - Risks for CNG injector freezing when using MPI systems - Fuel system fouling

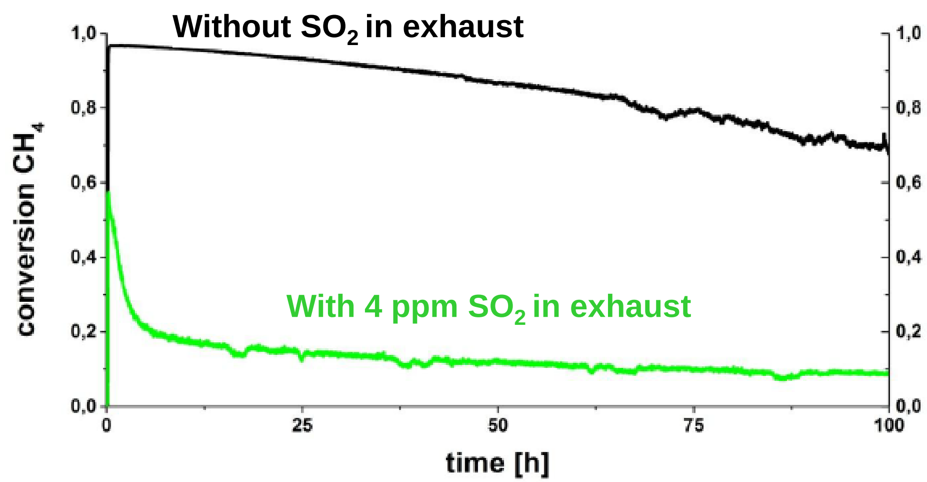
Catalytic conversion of methane in exhaust requires higher temperatures. Innovative coatings help reducing CH_4 light-off temperatures.

LOW SULFUR LEVELS IN NG REQUIRED TO AVOID RAPID POISONING OF CATALYST



Source: VKA. RWTH Aachen, 2014

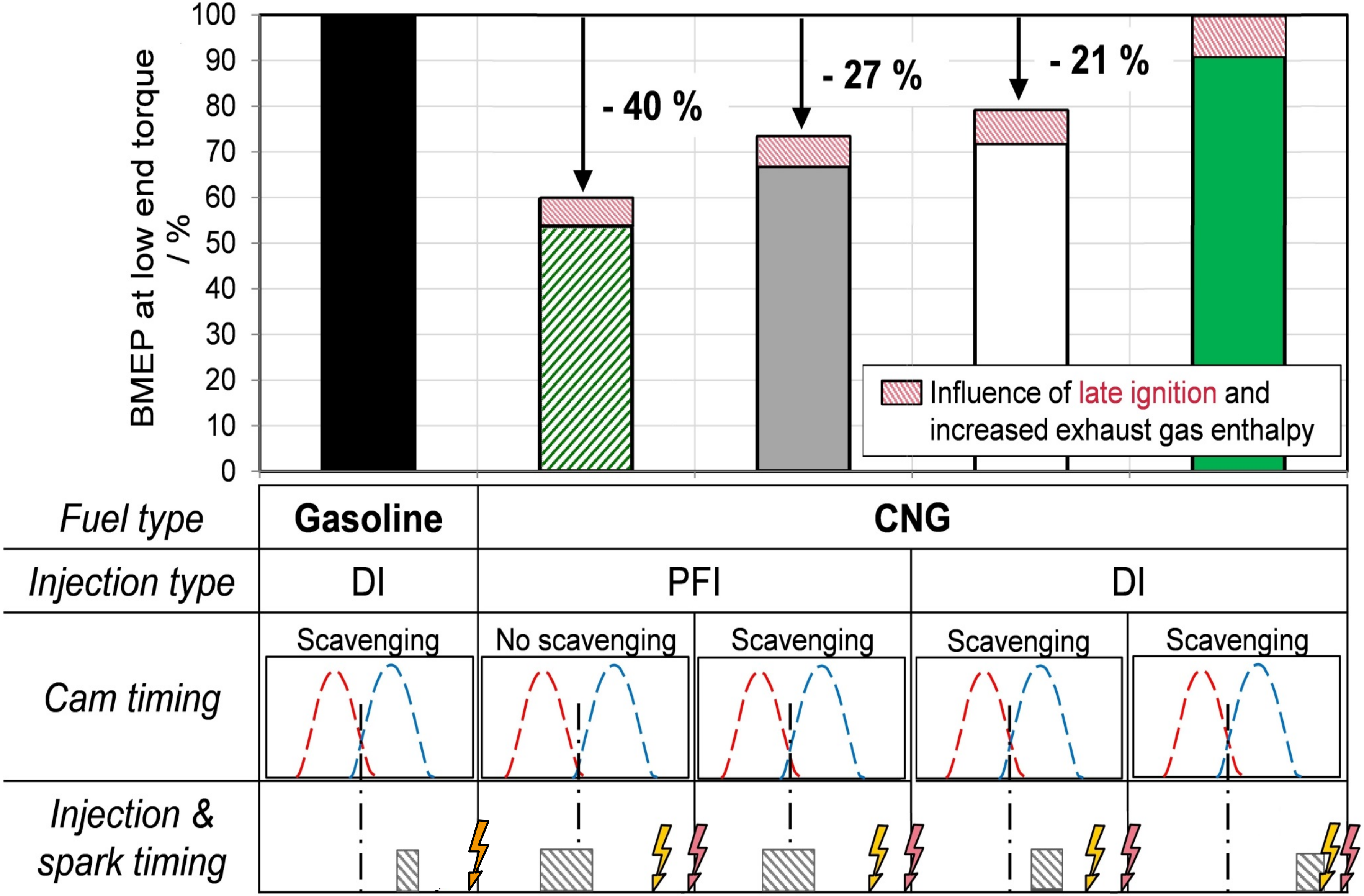
- German automotive NG standard DIN 51624 defines sulfur content < 10 mg/kg
- This is in agreement with liquid fuels



Source: Investigation of mechanism of catalytic methane reduction; Schwarzer, Endruschat, et al., KIT Karlsruhe; Final report, FVV-project No. 1134, 2014

Footnote

Optimization of CNG operation at low-end-torque: Performance of gasoline DI can be achieved with CNG DI

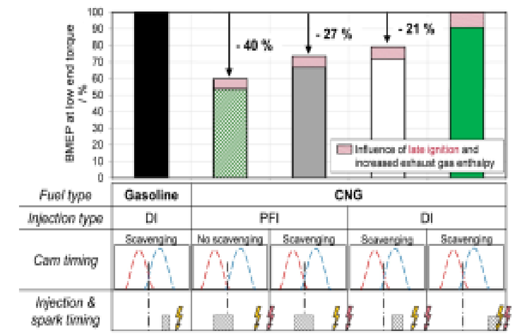


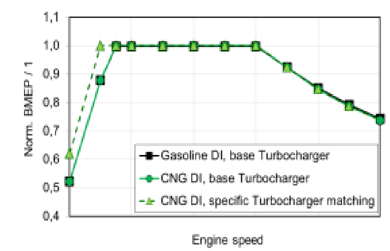
Source: Baumgarten et al.: CNG-Specific Downsizing- Potentials and Challenges, Vienna Motor Symposium 2015

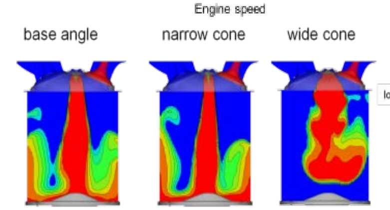
Dedicated NG engines achieve higher CO2 savings than multi-fuel engines, as they make no compromises

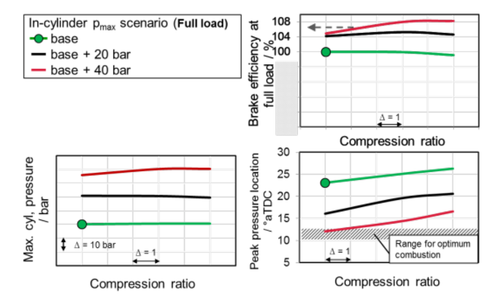
TECHNOLOGY STEPS FOR HIGH-EFFICIENCY DEDICATED NG ENGINES

1. Direct injection is the key technology to CNG performance equivalent to gasoline.
   - It allows scavenging of charge air to enhance turbo run-up without CH4 slip
2. A CNG-specific turbocharger match combines the advantages of NG - CO_2-saving and low fuel costs - with fun-to-drive
3. In order to achieve best results a detailed optimization of the combustion system is required.
4. The adaptation of the compression ratio offers significant additional benefits, but may require modification to the base engine in term of thermo-mechanic stresses.









Source: Baumgarten et al.: CNG-Specific Downsizing- Potentials and Challenges, Vienna Motor Symposium 2015

Footnote

Agenda

- Boundary conditions and technology drivers
- Customer and OEM benefits
- NG vehicle market
- Engine technology – current and future
- Methane fuels – status and requirements
- Summary & outlook

Footnote

Dedicated High-Efficiency NG engines require smaller fuel variations for optimal performance and damage-free operation

CNG GAS QUALITIES OBSERVED IN THE FIELD SHOW SOME IMPORTANT VARIATIONS

		Reference Gases		Typical Qualities		
		H-Gas G20	L-Gas G25	H-Gas Russia	H-Gas blended	L-Gas Holland
Composition						
Methane	Vol.-%	100,00%	86,00%	98,37%	84,77%	83,77%
Ethane	Vol.-%	0,00%	0,00%	0,51%	5,82%	3,51%
Propane	Vol.-%	0,00%	0,00%	0,17%	1,46%	0,73%
Butane	Vol.-%	0,00%	0,00%	0,06%	0,41%	0,24%
CO2	Vol.-%	0,00%	0,00%	0,06%	1,42%	1,41%
N2	Vol.-%	0,00%	14,00%	0,81%	5,99%	10,22%
O2	Vol.-%	0,00%	0,00%	0,00%	0,00%	0,00%
Characteristics						
Heating Value	kWh/m³	10,00	8,53	9,97	10,06	9,30
Heating Value	MJ/kg	50,00	38,87	49,23	43,37	40,34
Heating Value	MJ/m³	36,00	30,71	35,89	36,22	33,48
Density	kg/m³	0,72	0,79	0,73	0,84	0,83
Stoichimetric A/F Ratio	kg/kg	17,3	13,5	17,0	15,0	13,9
Mixture Heating Value	MJ/m³	3,38	3,33	3,39	3,39	3,36
Necessary Inj. Time Corr.	%	0,00%	16,28%	0,12%	0,06%	8,09%
Methane Number	-	100	>100	96	78	86

Different CNG qualities require fuel quality adaptation

Certain CNG qualities can result in significantly lowered knock resistance

Source: FEV

Footnote

Further content of Natural Gas for automotive use will need standardisation. If the grid is to be used for delivery to stations, this applies to all NG in the grid.

GRADES MAY DIFFER BY MN AND ENERGY CONTENT, BUT NEED TO RESPECT LIMITS ON OTHER COMPONENTS

Parameter	Unit	Min	Max	prEN 16723-2	prEN 16723-1	FprEN 16726	Comment
Net Wobbe Index (H-Gas)	MJ/m³	41.9	49.0	+	+	+	
Net Wobbe Index (L-Gas)	MJ/m³	40.5	-	+	+	+	no upper limit → transition to H-Gas
Lower Heating Value (H-Gas)	MJ/kg	44	-	+	+	+	
Lower Heating Value (L-Gas)	MJ/kg	39	-	+	+	+	
Sulfur Total	mg/m³	-	10	+	+	+	including odorization
Methane Number (high grade)	MWM	80	-	+	+	+	dual fuel requirement, non-grid distribution
Methane Number (regular grade)	MWM	70	-	+	+	+	
Total Siloxanes (calculated as Si)	mg/m³	-	0.1	+	+	+	capable test method to be agreed
Hydrogen	% v/v	-	2	+	+	+	according to ECE 110
Compressor Oil	mg/m³	-	tbd.	+	-	-	method and limits to be agreed (automotive standard only)

Lambda sond mistuning

Risk of steel tank H2 embrittlement

Fouling of fuel rail, injectors, valves, and combustion chamber

27

Source: Kramer et al., "Methane Fuels: European Automotive Fuel Quality and Standardization Requirements", Gas Powered Vehicles Conference Stuttgart, October 21st, 2015

Footnote

Agenda

- Boundary conditions and technology drivers
- Customer and OEM benefits
- NG vehicle market
- Engine technology – current and future
- Methane fuels – status and requirements
- Summary & outlook

Footnote

Using CNG in road transport can increase NG business significantly. It is also the bridge to run cars with gas from renewable sources.

CNG IN TRANSPORT CAN REDUCE GHG EMISSIONS WHILE BEING COMMERCIALLY PROFITABLE

Natural Gas as fuel for transport

End User Benefits

- Lower fuel cost
- Green consciousness satisfied (CO_2↓ PM ↓↓)
- CNG trucks may deliver goods at night time in areas where diesels are prohibited
  - Better traffic flow at day-time
  - More efficient deliveries

Car Maker Benefit

- Easier compliance with CO2 fleet emission limits
- PM/PN and noxious emission limits with rather easy EATS technology
- Dedicated CNG engines can be derived from standard engine family
- Cheap and long-lasting energy storage

Energy Provider Benefit

- Steadily growing market
  - LNG blue corridors
  - Growing CNG fleet
- Enabler for transition to renewable energy provision
  - Bio-methane, Power to methane
- Uses/extends existing network

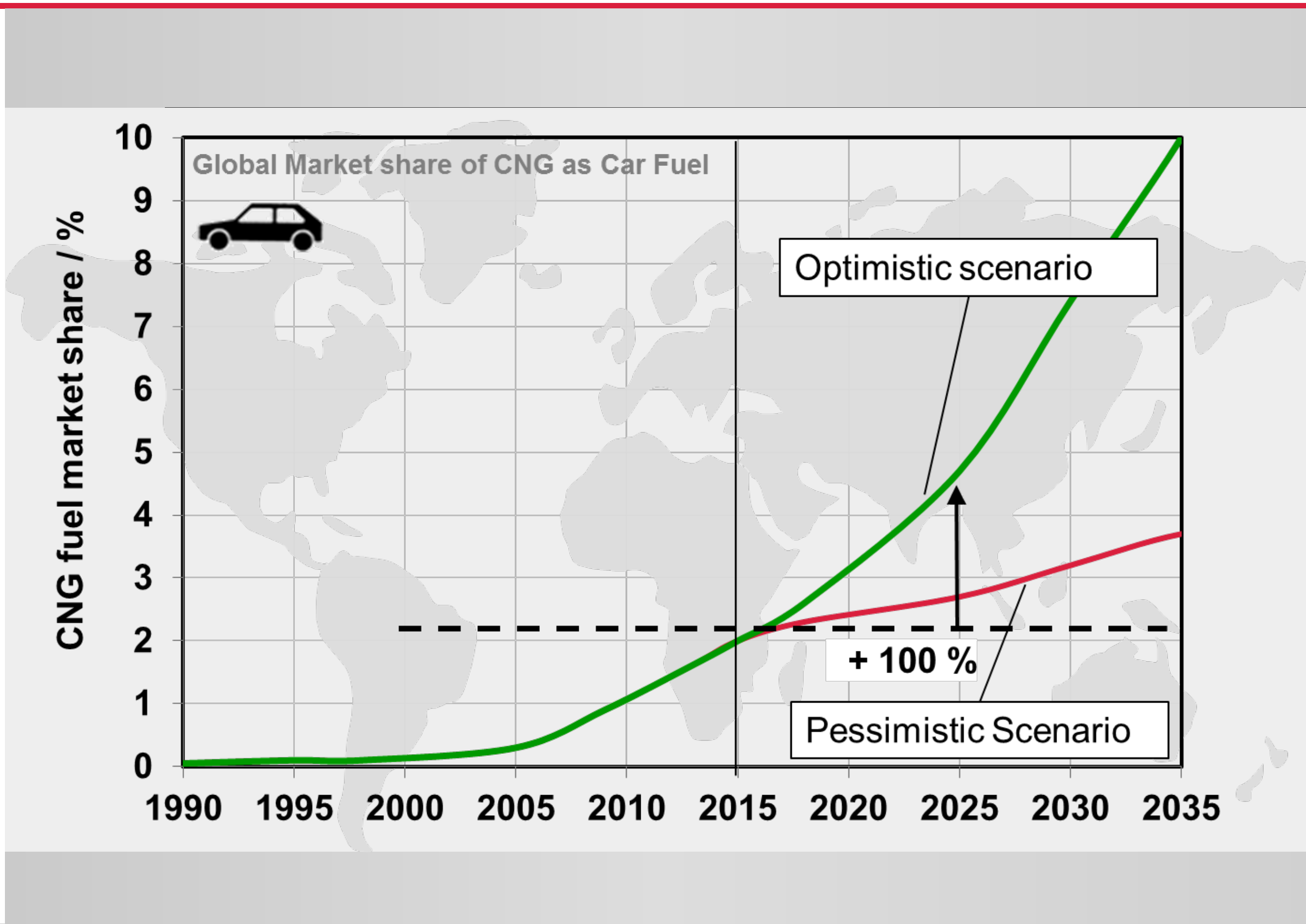
To Do's

- Better marketing of CNG cars → OEMs
- Better coverage and better visibility of NG fuel stations → CNG providers
- Improvement/definition of NG fuel standards → CNG providers, car makers

Using CNG in road transport can increase NG business significantly. It is also the bridge to run cars with gas from renewable sources.

Prepared for

BDEW-Fachkongress
Treffpunkt Netze 2016



Kontakt:
schernus@fev.com

Berlin, 2016-03-02

Christof Schernus, RD, Knut Habermann, BGP,

I M P R E S S U M

BDEW-Fachkongress Treffpunkt Netze 2016
1. und 2. März 2016, Maritim Hotel Berlin

Veranstalter und Herausgeber
EW Medien und Kongresse GmbH
Reinhardtstr. 32
10117 Berlin
www.ew-online.de

Ansprechpartner Bestellung
Katja Scheib
E-Mail: katja.scheib@ew-online.de

März 2016