Methane as Fuel: Opportunities and Challenges
Methan als Kraftstoff: Chancen und Herausforderungen

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Go Further

- Challenges of future mobility
- Prospects of CNG / e-methane as fuel
- State of the art: methane engine technology
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- H2020 - project landscape CNG / methane
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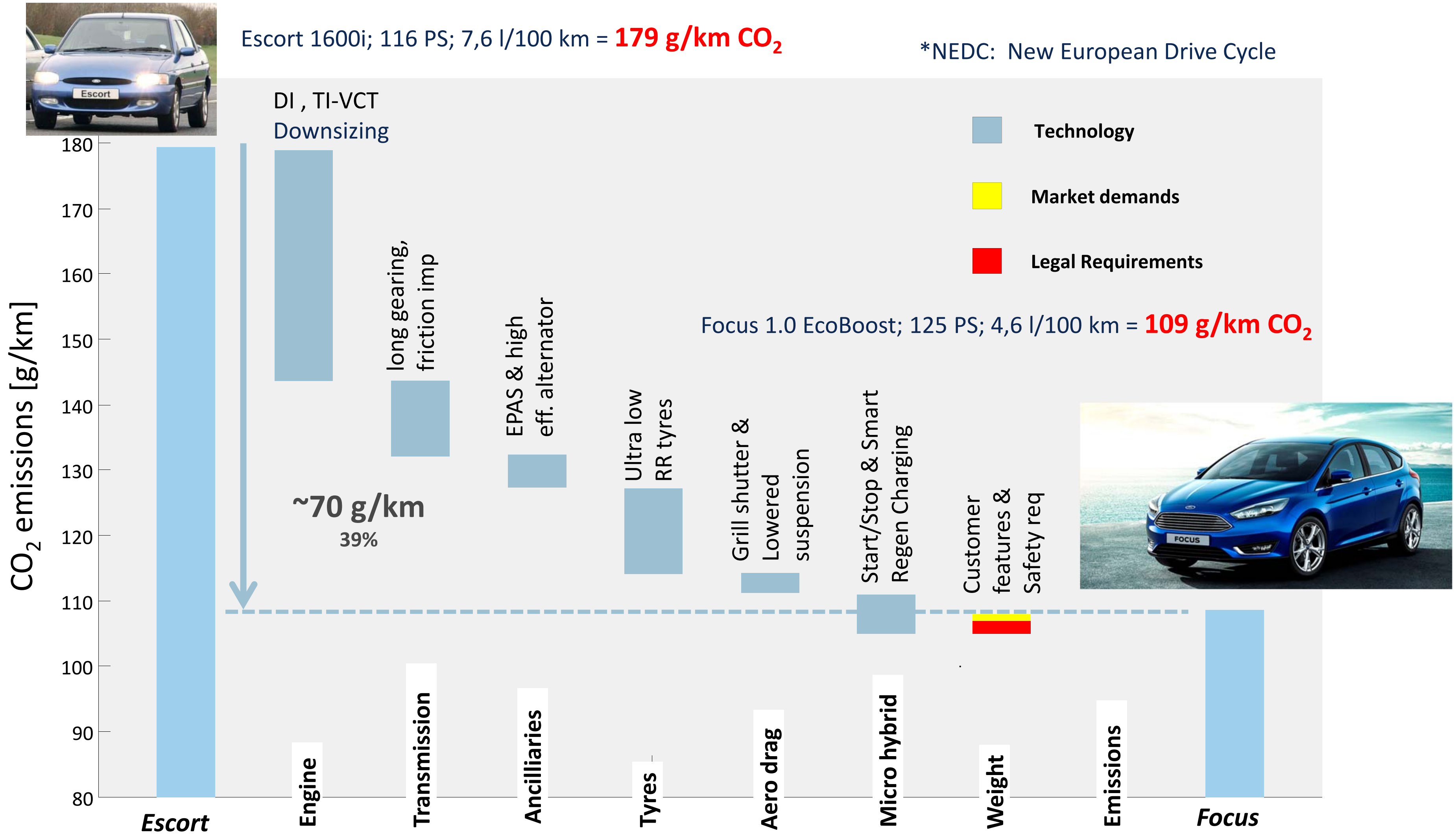
Challenges of future mobility

CO2 emission reductions in recent decades (NEDC*)



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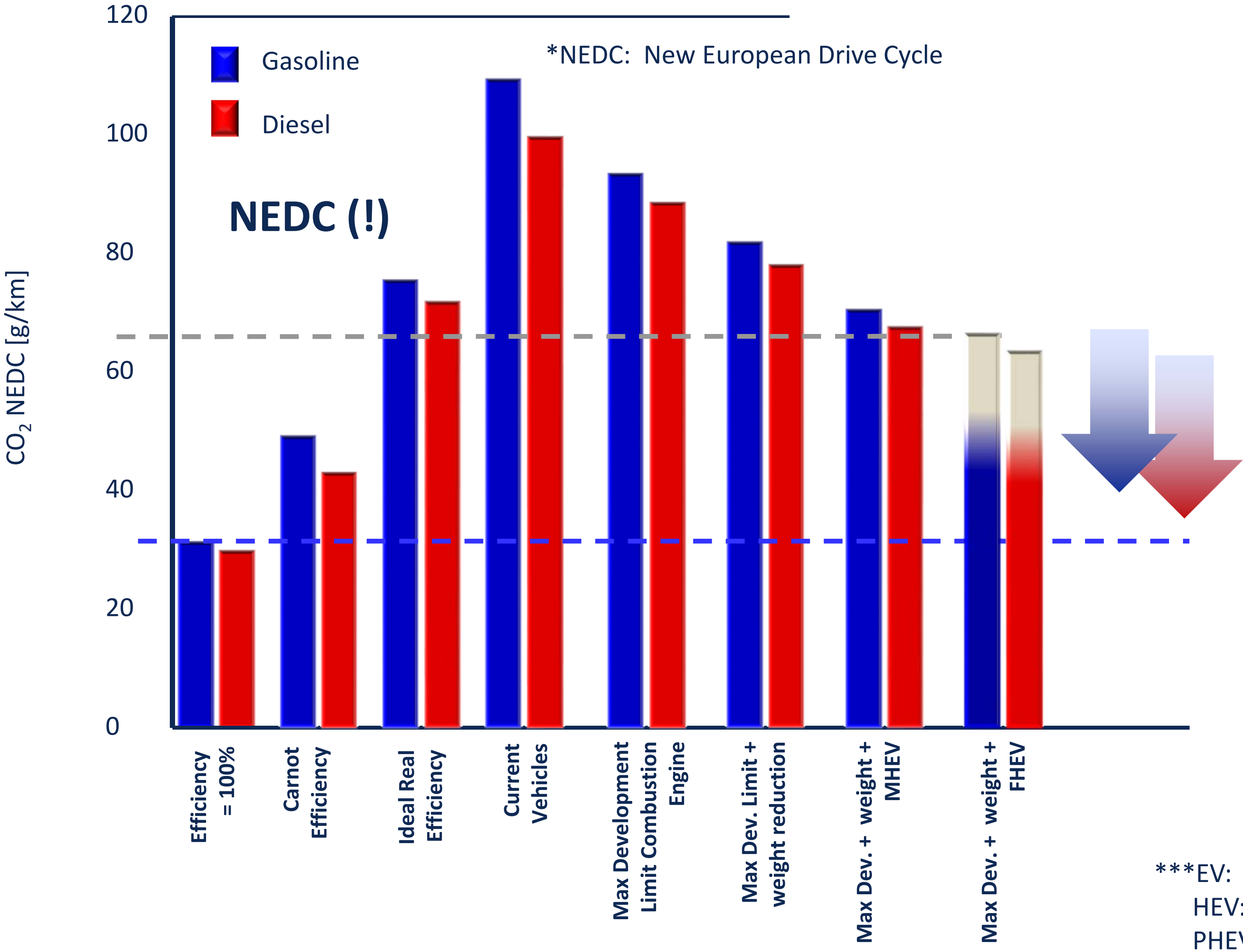
Challenges of future mobility

Assessment of CO_2 reduction potential with gasoline, diesel technology (NEDC*)



- **TtW CO_2 targets:**
  - **2020: 95 g/km**
  - **2030: -30% (~67 g/km) under discussion**
- **WLTP** exposes an even bigger challenge on CO_2!**
- **Customer demand for larger cars or SUVs intensify CO_2 challenge!**
- **Further TtW CO_2 reduction** only possible via PHEV, EV, FCEV*** (technological, economical limits)
- WtW approach seems meaningful
- **So far, no WtW approach in European CO_2 regulation!**

***EV: Electric Vehicle
HEV: Hybrid EV
PHEV: Plug-in HEV
FCEV: Fuel Cell EV
MHEV: Mild HEV
FHEV: Full HEV

** WLTP: Worldwide harmonized Light vehicles Test Procedure

**Typical C-Car:
1360kg, 1.3 kWh
for NEDC**

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Challenges of future mobility

Battery Electric vehicles and fuel cell vehicles

Re-Fueling Time		Infrastructure
Diesel/Gasoline Vehicle Refueling Time <10 sec / 100km	35 l/min filling station ~20.5 MW charging power	**Fully developed** > 14,000 pumps
Battery Electric Vehicle Recharging Time ~6 hours / 100km to ~7 min / 100km	2,3 kW (household) 50 kW – 120 kW (fast charging)	**Today: increasing**
Battery Electric Vehicle Recharging Time (future) ~3 min / 100km to ~1 min / 100km	Up to 350 kW planned (German consortium) with up to 1 MW under study (being implemented in China)	**Future: under investigation**
Fuel Cell Electric Vehicle Refueling Time ~30 sec / 100km	3-5 min for 4-7kg H_2 880 bar filling station, H_2 preconditioned to -40°C ~3 MW charging power	**Insignificant** << 100 pumps ~ no pipelines
Bio- / PtG-Methane / CNGV Refueling Time ~30 sec / 100km	2-3 min for 20kg CH_4 ≤ 300 bar filling station (30 – 40 kW compressor: parallel re-fueling of 2 vehicles possible) ~6.5 MW charging power	**Basis available** > 900 pumps ~ 400k km pipelines ~ 100k NG vehicles fully compatible

- **BEV / PHEV / FCV* → limited customer acceptance today**:
  - BEV: extended re-charging time and limited range
  - BEV: incomplete re-charging infrastructure
  - FCV: nearly no H_2 infrastructure
  - **BEV / PHEV / FCEV*: vehicle costs**
- BEV / PHEV* are currently introduced into the market and definitely will play a significant role in the future, but cannot fulfill all customer demands today
- FCEV* under consideration
- **Supplementary low CO_2 technologies required (long distance, low cost, fast market penetration)**

CNGV: Compressed Natural Gas Vehicle
PtG: Power-to-Gas

*EV: Electric Vehicle
BEV: Battery EV
HEV: Hybrid EV
PHEV: Plug-in HEV
FCEV: Fuel Cell EV

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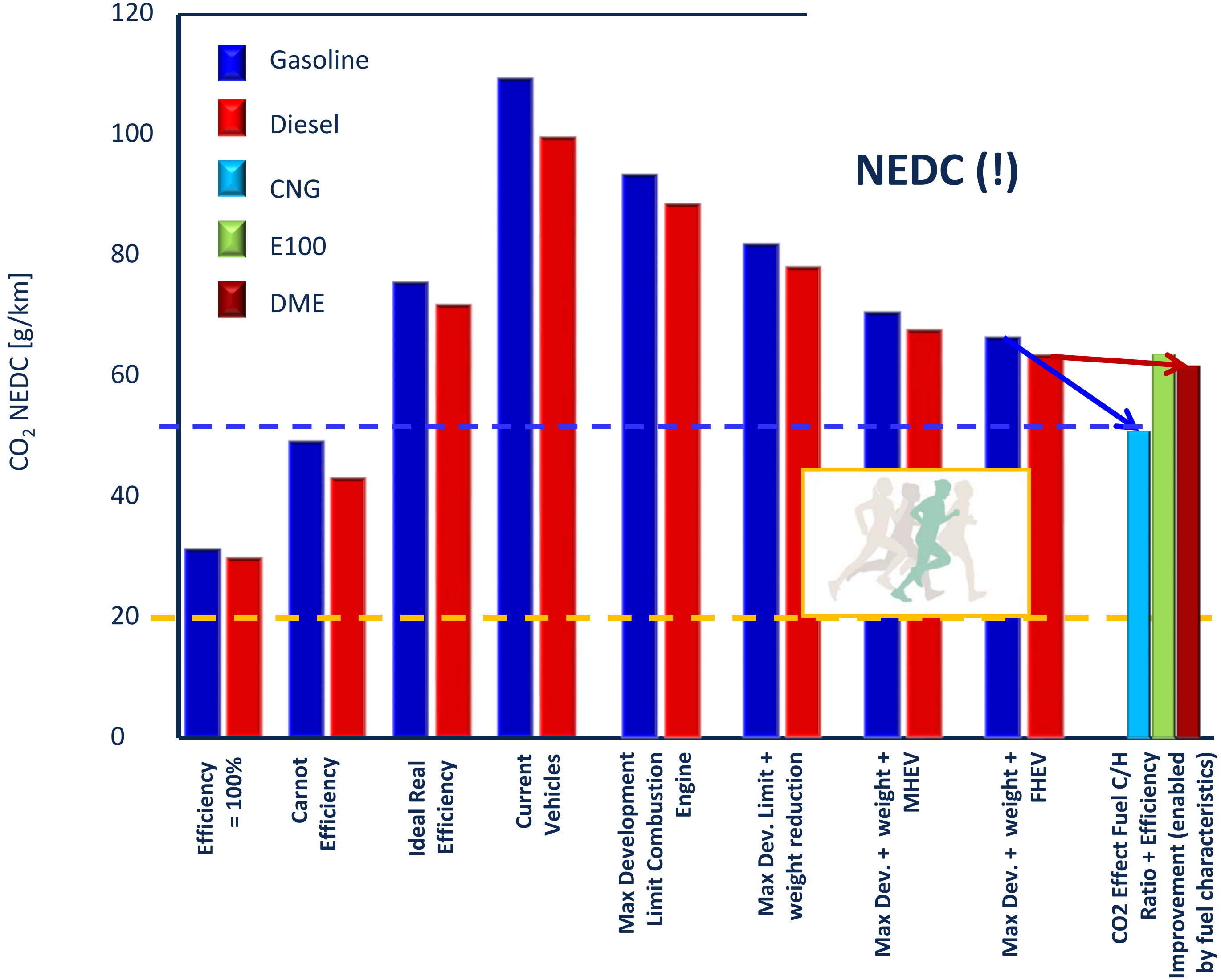
Challenges of future mobility

Lower C/H ratio of alternative fuels enables significant TtW CO_2 reduction



WtW Option: Complete defossilisation with e-fuels (PtX) out of renewable electricity (wind / solar)

PtX: Power-to-X(= any fuel)

Further Challenge: Zero Impact Emissions !

For comparison: marathon runner (75 kg man, 4:15 finisher) ~ 20 g CO_2/km (Additional to basic metabolic rate)

MEMO
EV: Electric Vehicle
HEV: Hybrid EV
MHEV: Mild HEV
FHEV: Full HEV

Typical C-Car: 1360kg, 1.3 kWh for NEDC

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Prospects of CNG / e-methane as fuel

Advantages - NG / methane combustion

- **More favorable C/H ratio than gasoline**
  → ~25 % CO_2 “Tank-to-Wheel” benefit (at same engine efficiency)
- **Low feedgas emissions:** in particular no soot

- **Very knock resistant** → ideal fuel for boosting and downsizing (RON > 120)
  - **High compression ratio (CR) enabler**
    → efficiency improvement
    → further CO_2 reduction
  - **High boost pressure enabler → downsizing enabler**
    → efficiency improvement by use of smaller engine architecture

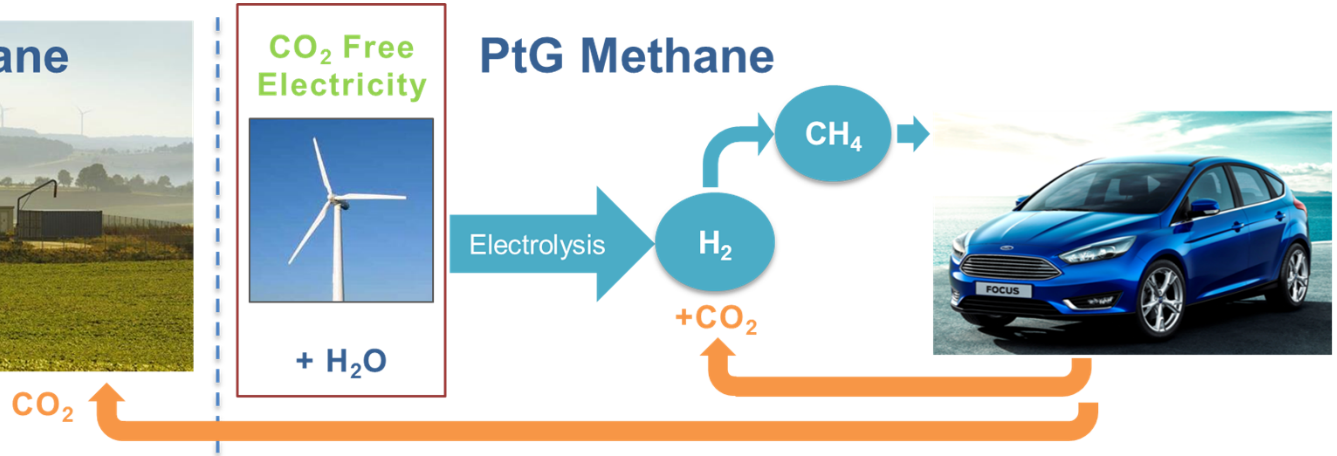
Prospects of CNG / e-methane as fuel

Picture: erdgas mobil / Danny Kurz Photography

- Fossil CNG: 25 % TTW CO_2 reduction vs. gasoline (C/H ↓)
- RON > 120: efficiency ↑ (optimized engine)
- No soot
- Low NOx (λ=1)
- Low fuel costs

Picture Source: erdgas mobil

- Fully compatible with CNG (no blend limit)
- Among all bio fuels: maximum land use efficiency and CO_2 reduction potential
- ~ 80 % WTW CO_2 reduction realistic
- Cost efficient bio fuel



- Fully compatible with CNG / bio methane (no blend limit)
- Land use efficiency significantly higher than bio fuels
- Simple and efficient PtX process
- **100% sustainable mobility possible** with overall use of regenerative electricity

Opportunity:

Develop "methane/ CNG vehicle market" with affordable CNG and then gradually shift to renewable energy supply.

Go Further

Prospects of CNG / e-methane as fuel

E-methane (PtG) future specification opportunities

		CNG (H-Gas) EN 16723-2		Opportunity E-Methane		
Parameter	**Unit**	**Min**	**Max**	**Min**	**Max**	**Effect**
Methane Number (MN)	- *(MWM method)*	65	-	98	-	Describes knock resistance of the fuel. Important for max. compression ratio, boosting capability. **E-methane: no dilution with C2+.** → **enhanced engine efficiency.**
Lower Heating Value (LHV)	MJ/kg	not in fuel standard *(often >44)*	-	50	-	Fuel energy content. Important for **mileage range and max. achievable power** (determined by injector flow limitations). **E-methane: no dilution with inert gases** → **enhanced mileage and specific power**
Total Sulfur	mg/m³	-	30	-	0	Important for zero impact emissions. Sulfur is poison for the catalyst. **No natural sulfur in e-methane.** **Sulfur free odorization** enables **sulfur free fuel.** → **reduced fuel demand for catalyst desulfurization** → **enhanced engine efficiency** → **reduced catalysts loading** (vehicle cost ↓)
Hydrogen	% m/m	-	2	-	2	Important for steel tank safety (acc. to ECE 110)
Compressor Oil	mg/kg	tbd.	tbd.	tbd.	tbd.	Important for injection system functionality. Method tbd.

E-methane opportunity: **Better fuel quality than conventional NG with dedicated E-Methane fuel standard.** → **Enabler for increased efficiency and performance vs. CNG.**

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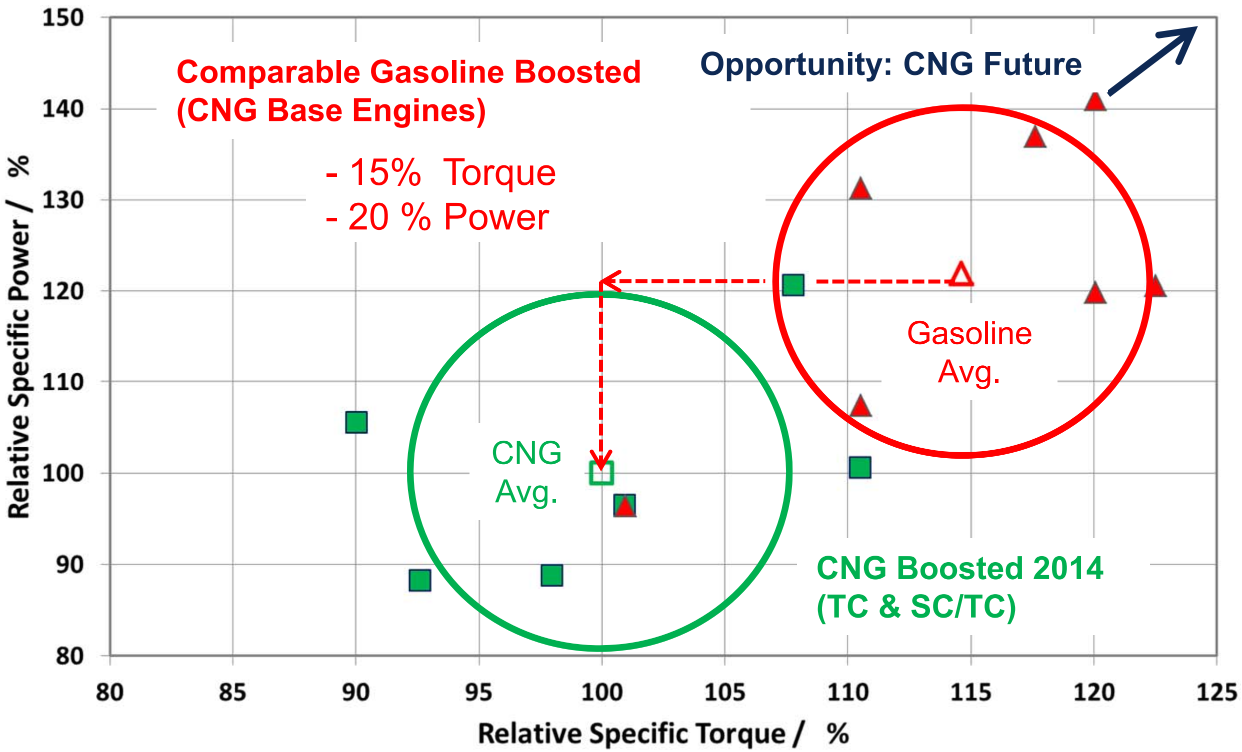
State of the art: methane engine technology

2014 EU CNG vehicle market: CNG port fuel injection (PFI)



→ torque penalty vs. gasoline DI: CNG displaces air → vol. effy. ↓

- Dedicated CNG DI engine: compensation of volumetric efficiency losses
- Enhanced downsizing by exploitation of high knock resistance of CH_4

  ⇒ Increased efficiency of CNG engines → less CO_2

- CNG specific torque: ~15% below comparable gasoline DI
- CNG specific power: ~ 20% below comparable gasoline DI

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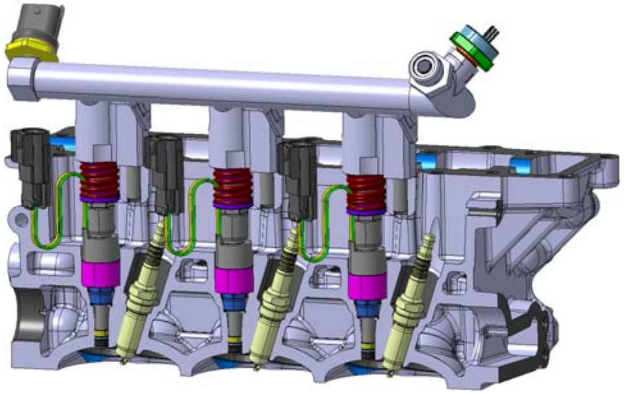
Opportunities of dedicated e-methane engines

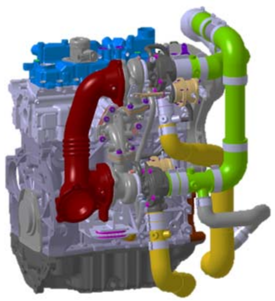
CNG / Methane Downsizing Enablers

- CNG direct injection



- CNG optimized engine architecture

- Advanced boosting systems

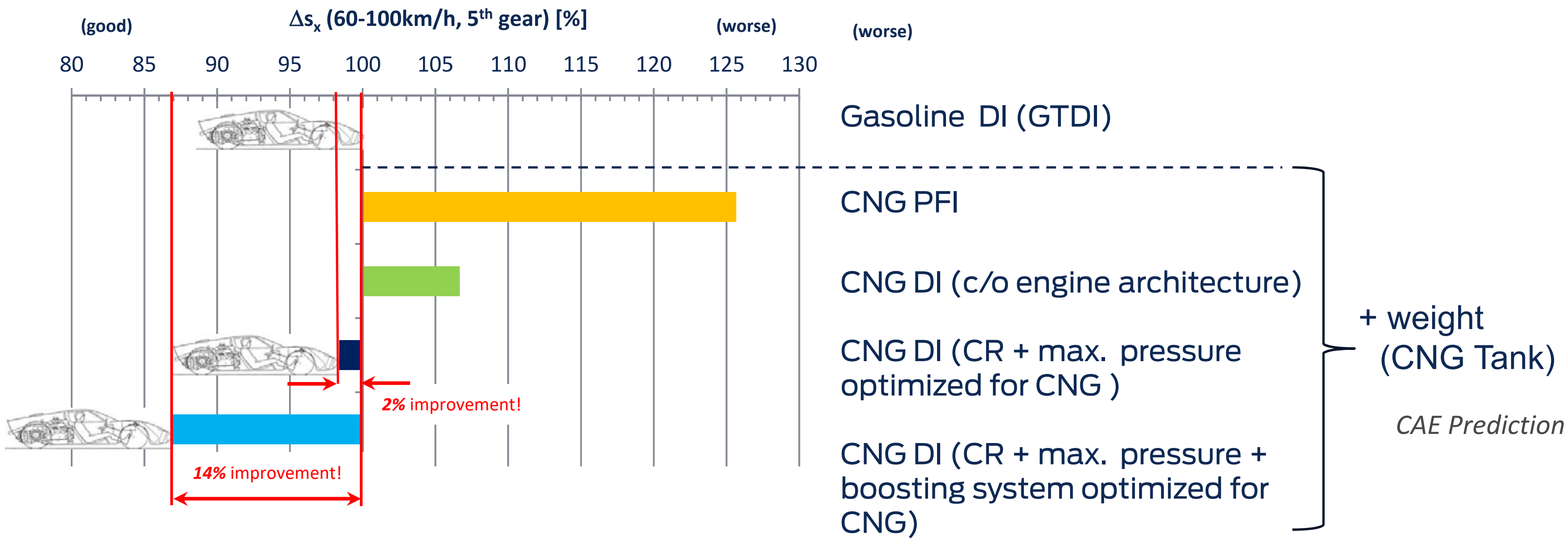


- The higher the knock resistance of the fuel, the higher the downsizing capability (e-methane opportunity)

Opportunities of dedicated e-methane engines

Effect on Vehicle Performance Attributes - Transient Response Walk

Simulation Results: Acceleration 60-100km/h in 5th gear



- **Dedicated CNG DI with optimized engine architecture, with additionally optimized boosting system, and operated with highly knock resistant fuel elevates performance level significantly**

Ford
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H2020 - project landscape CNG / methan

GasOn – Gas-Only Internal Combustion Engines (WP3)

GAS ON

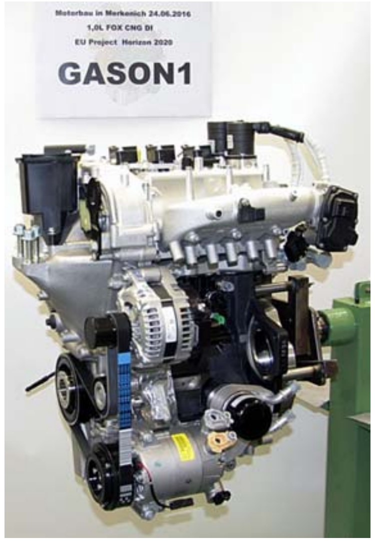
*H2020 GV-3-2014 Future natural gas powertrains and components for cars and vans (*Project number 652816*)*

- Ford Grand C-MAX (7 Seat Van)
- Dedicated “Gas Only” powertrain, engine optimized for CNG / methane operation
- 600 km mileage
- 20% CO_2 reduction vs. “Best-in-Class” CNG Vehicle 2014 (CO_2 eq. < 100 g/km)
- 110 kW, 240 Nm
- EU6+ emission level

H2020 - project landscape CNG / methane

GasOn – Gas-Only Internal Combustion Engines (WP3)

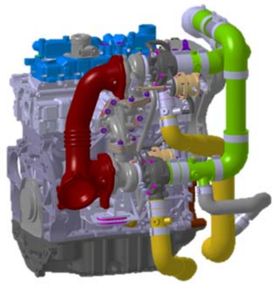
GasOn Technologies



Downsizing:

- 1.0l 3 Cylinder dedicated NG Engine

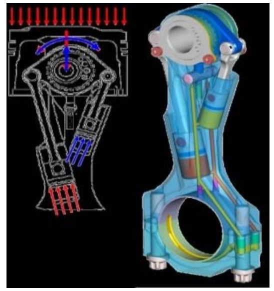
Downsizing enablers: re-gain power and torque



Parallel Sequential Twin Turbo Boost System

CNG Direct Injection (CNG DI)

High CR enabler



Variable Compression Ratio (VCR)

Part Load De-throttling

Continuously Variable Valve Lift System (CVVL)

Weight Reduction

CNG Type 4 Tanks

*H2020 GV-3-2014 Future natural gas powertrains and components for cars and vans (*Project number 652816*)*

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H2020 - project landscape CNG / methane

Thomson

Mild Hybrid cost effective solutions for a fast market penetration.

Low Carbon Fuel: CNG

48V Mild Hybrid Powertrain (mHEV)

↓

Affordable, dedicated CNG Hybrid Electric Vehicle (HEV) (basis 1.0 CNG-DI)

Ford Grand C-Max

Major Objectives:

- Driveability as with 1.5l 4-cyl. gasoline engine (110kW)
- CO_2 ≤ 1.5TDCi Diesel 88kW
- Projected costs: below 1.5 TDCi Diesel 88kW (EU7).

Go Further

H2020 - project landscape CNG / methane

Outlook:
MethQuest – MethCar

METHQUEST

Erzeugung und Einsatz von Methan aus erneuerbaren Quellen in mobilen und stationären Anwendungen

Application for
07/2018- 06/2021

- New dedicated methane engine
- Lower complexity
- Better efficiency
- Production capability of methane DI system
- Determination of S, H2, Compressor Oil Limits

Verbund 1 **MethFuel**	Verbund 2 **MethCar**	Verbund 3 **MethPower**	Verbund 4 **MethMare**
Innovative Metha-nerzeugung auf Basis erneuerbarer Quellen	Methanmotoren für PKW	Effiziente und saubere Nutzung von erneuerbaren, methanbasierten Kraftstoffen zur Stromerzeugung	Effiziente und saubere Nutzung von erneuerbaren, methanbasierten Kraftstoffen in maritimen Anwendungen

Verbund 5 **MethGrid**
Sektorenkopplung in einem Microgrid am Beispiel des Binnenhafens Karlsruhe

Verbund 6 **MethSys**
Systemanalytische Untersuchungen zur Evaluierung der Rolle von EE-Methan

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Summary & Conclusions

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FCEV: Fuel Cell EV

- Challenge for automotive transportation is GHG (CO_2)
- **TTW CO_2 reduction** potential with fossil gasoline / diesel is limited
- **Elimination of TTW CO_2** possible with electrification (BEV, PHEV)* or carbon free fuel (H_2, FCEV*)
- BEV / PHEV / FCEV* → limited customer acceptance (re-charging time, infrastructure, costs)
- **Low carbon fuels**, as e.g. methane, enable significant step down in **TTW CO_2 emissions**
- **WTW basis: CO_2 neutral mobility also possible when vehicle CO_2 emissions are "recycled" into sustainable fuels** (→ PtX fuels as e.g. e-methane) → opportunity of fast market introduction
- CNG mobility is an introduction scenario for sustainable mobility via e-methane + bio methane
- Maximum efficiency achievable with dedicated, “genuine” methane engines
- Further efficiency potential by standardized high quality e-methane (high MN, LHV; low sulfur)
- A “Methane-HEV*” is an interesting concept in particular with regard to CO_2 avoidance costs
- The EU actively supports NG / methane mobility projects
- Ford R&A is actively involved in several NG / e-methane EU research activities (Horizon 2020: GasOn, Thomson, MethQuest)