Go Further

Dedicated CNG / E-Methane Vehicles & Horizon 2020 „GasOn“ WP3 Status

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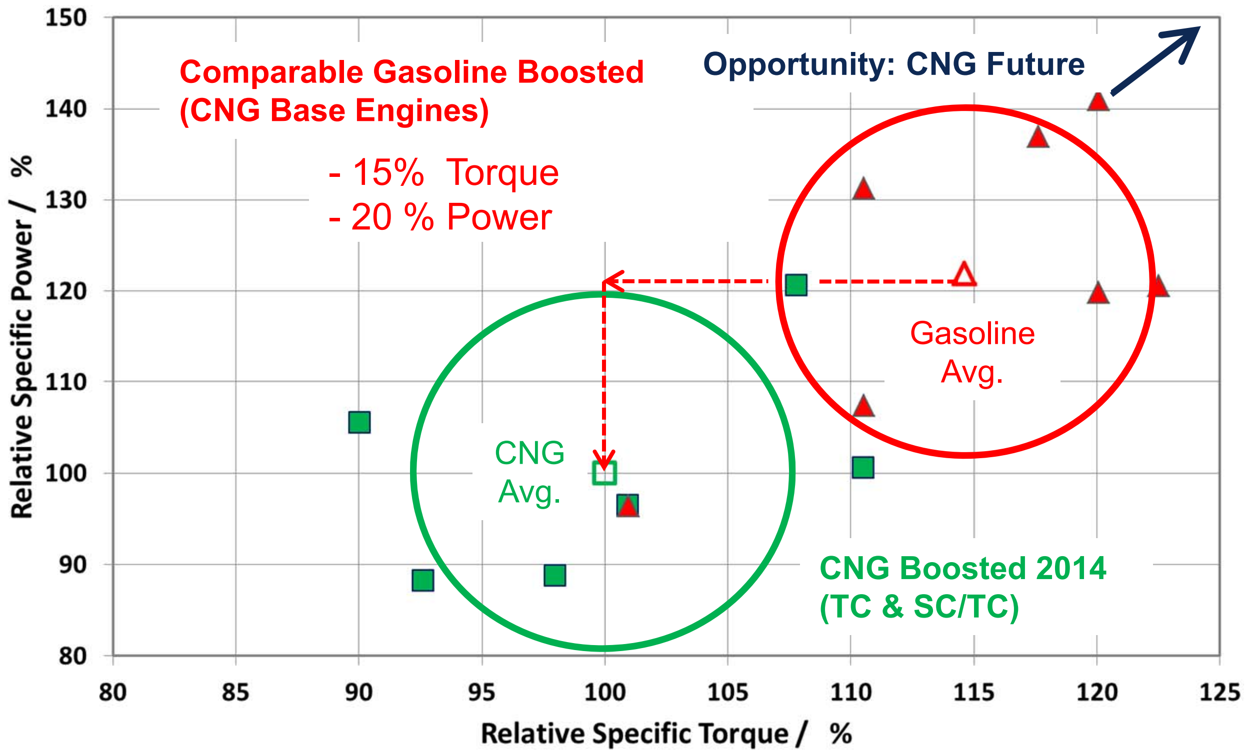
JEC Meeting, Ford RIC Aachen, Dec. 20th 2017

State of the art: methane engine technology

Go Further

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

H2020 – Project: GasOn WP3 Target Setting

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

CO2 reduction walk for Generic CNG Base Vehicle Grand C-MAX 1.6l Ecoboost CNG PFI

- CNG base vehicle: Grand C-MAX 1.6l Ecoboost (gasoline)

	FC	CO2	FC/CO2	CO2 Benefit				
	kg/100km	g/km	gCO2 / kgCNG	Step	Total	Version	CO2 Impact	Performance Impact
Powertrain	(neat CH4)			%	%			
1.6l Ecoboost Gasoline DI	4.80	149	31.0			Gasoline Base	c/o	c/o
1.6l Ecoboost CNG PFI	4.21	113	27.5	*24.0*		Apply CNG PFI system	CO2 benefit due to more favorable C/H ratio of CNG vs. gasoline	Low end torque not achieved below 2000 rpm - not compensated: reduced performance vs. gasoline version
1.6l Ecoboost CNG PFI	4.45	122	27.5	*-8.1*		Add 233kg for 600km range CNG Type 1 tank system (5 canisters)	CO2 penalty because of on-weight of CNG tank system	Reduced performance because of on-weight of CNG tank system (not compensated)
1.6l Ecoboost CNG PFI	4.53	**124**	27.5	*-1.7*	*16.5*	Short final drive applied to compensate weight penalty of CNG tanks: Base CNG	CO2 penalty because of higher rpm caused by shorter final drive	Performance loss of additional tank system weight compensated (CNG PFI penalty not compensated)

Grand C-MAX 1.6l Ecoboost CNG PFI

- CO2: 124 g/km

H2020 – Project: GasOn WP3 Targets

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

BIC 2015 C-Class Vans (7 seats) – CO_2 Emissions

Generic Base Vehicle: Ford Grand C-MAX CNG PFI - BIC Competitor Comparison

Vehicle Data	Generic Ford Grand C-MAX 1.6l Ecoboost CNG PFI	VW Touran 1.4l TSI Ecofuel	Opel Zafira Tourer 1.6 CNG Turbo ecoFLEX	Last Ford C-MAX 2.0l CNG (MY 2005 … 2009)
CO2 / g/km	124	128	129	148
0 – 100 km/h / s	~ 10.5	10,2	11,5	10,9
Seats / -	7	7	7	5
Weight / kg	1729	1697	1735	1496
Power / kW	110	110	110	93
Torque / Nm	220 … 240	220	210	156
At lowest rpm	~ 2000	1500	2300	4500
Mileage / km	600	500	530	250




H2020 – Project: GasOn – Technology

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

GasOn – Gas-Only Internal Combustion Engines (WP3)

GasOn Technologies

Downsizing:

- 1.0l 3 Cylinder dedicated NG Engine

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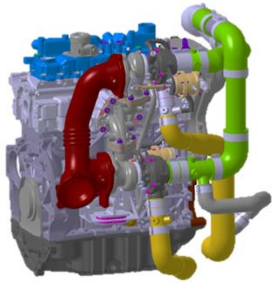
Downsizing enablers: re-gain power and torque



Parallel Sequential Twin Turbo Boost System

CNG Direct Injection (CNG DI)

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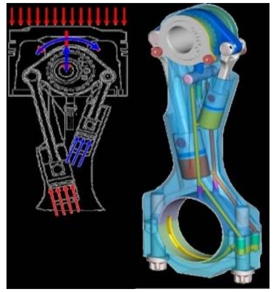
High CR enabler



Variable Compression Ratio (VCR)

↓

Part Load De-throttling

Continuously Variable Valve Lift System (CVVL)

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Weight Reduction

CNG Type 4 Tanks

H2020 – Project: GasOn WP3 Target Setting

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

CO2 reduction walk for Dedicated CNG GasOn Vehicle Grand C-MAX 1.6l Ecoboost CNG DI

- Generic base vehicle: Grand C-MAX 1.6l CNG PFI

	FC	CO2	FC/CO2	CO2 Benefit				
	kg/100km	g/km	gCO2 / kgCNG	Step	Total	Version	CO2 Impact	Performance Impact
Powertrain	(neat CH4)			%	%			
1.6l Ecoboost CNG PFI	4.53	**124**	27.5			BASE CNG	-	-
1.0 Adv. Twin Boost CNG DI (c/o CR; c/o valvetrain int.)	4.00	110	27.5	*11.5*		Replace 1.6l Ecoboost CNG PFI engine with 1.0l Ecoboost CNG DI engine	CO2 benefit because of downsizing (de-throtteling, friction reduction)	None: Compensated by advanced boosting system and CNG-DI
1.0 Adv. Twin Boost CNG DI (c/o CR; c/o valvetrain int.)	3.75	106	27.5	*3.5*		Type 1 CNG tanks replaced by Type 4, gasoline tank removed, + weight impact of 3 cyl. vs. 4 cyl. engine	CO2 benefit because of weight reduction	Improved with less vehicle weight
1.0 Adv. Twin Boost CNG DI (c/o CR; c/o valvetrain int.)	3.70	105	27.5	*1.4*		Long final drive applied (affordable because of weight reduction)	CO2 benefit because of down-speeding	Performance gain of weight reduction compensated
1.0 Adv. Twin Boost CNG DI (VCR & VVL)	3.51	100	27.5	*4.9*	**20**	High CR and Intake VVL applied	CO2 benefit because of higher combustion efficiency (high CR) and de-throtteling (VVL)	Slightly improved performance expected

Grand C-MAX 1.6l Ecoboost CNG DI GasOn

- CO2: 100 g/km

H2020 – Project: GasOn – 1st Achievements

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

GasOn – Gas-Only Internal Combustion Engines (WP3)

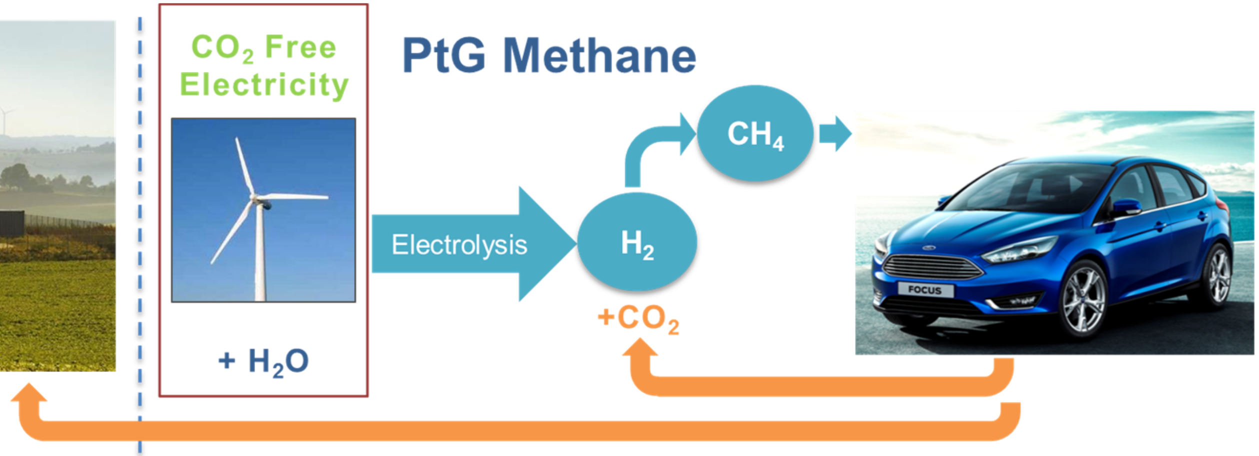
- Ford Grand C-MAX (7 Seat Van) built
- Dedicated "Gas Only" powertrain, engine optimized for methane operation (Non-VCR version with high combustion pressure capable engine architecture)
- > 600 km mileage
- ≥ 20% CO_2 reduction vs. "Best-in-Class" CNG Vehicle 2014 (CO_2 eq. ≤ 100 g/km)
- 110 kW, 240 Nm
- EU6+ emission level

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.

Prospects of CNG / e-methane as fuel

Go Further

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.