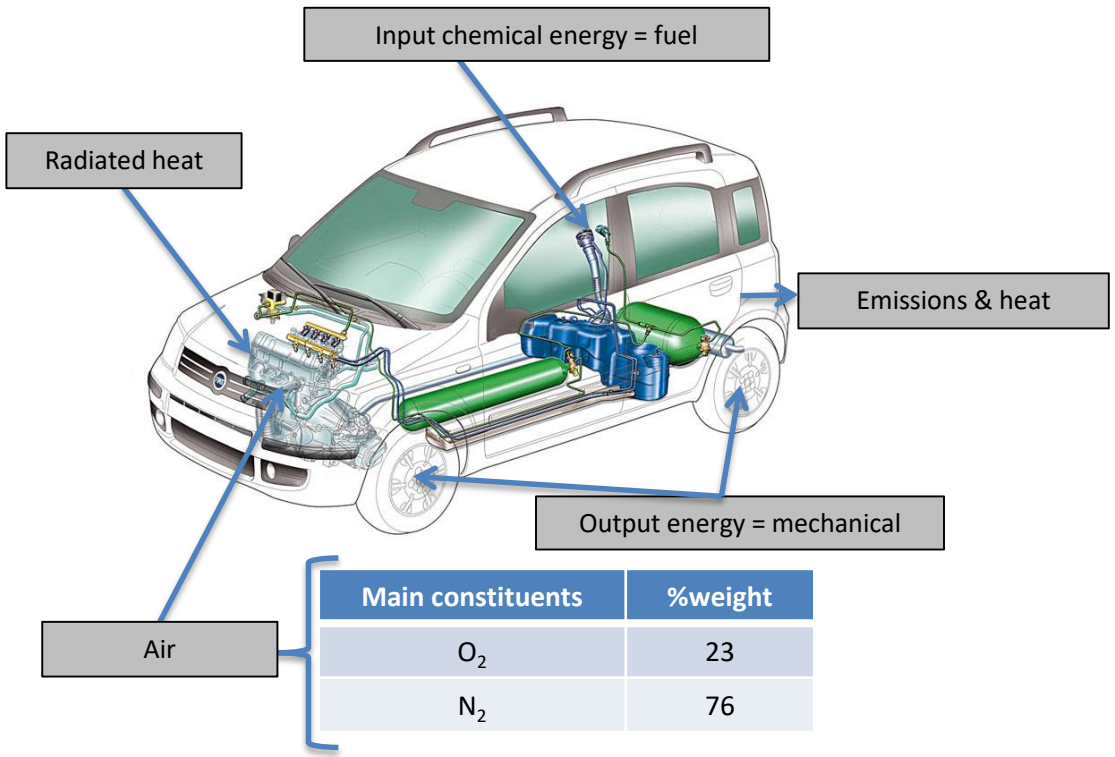
PROJECT FINAL RESULTS

The issue: vehicle emissions

FUEL (C, H, O) + AIR (N_2+O_2) → H_2O + CO_2 + pollutants



Main constituents	%weight
O_2	23
N_2	76

Global impact

Emission	%weight
CO_2	18
H_2O	8,5
O_2	0,6
N_2	72

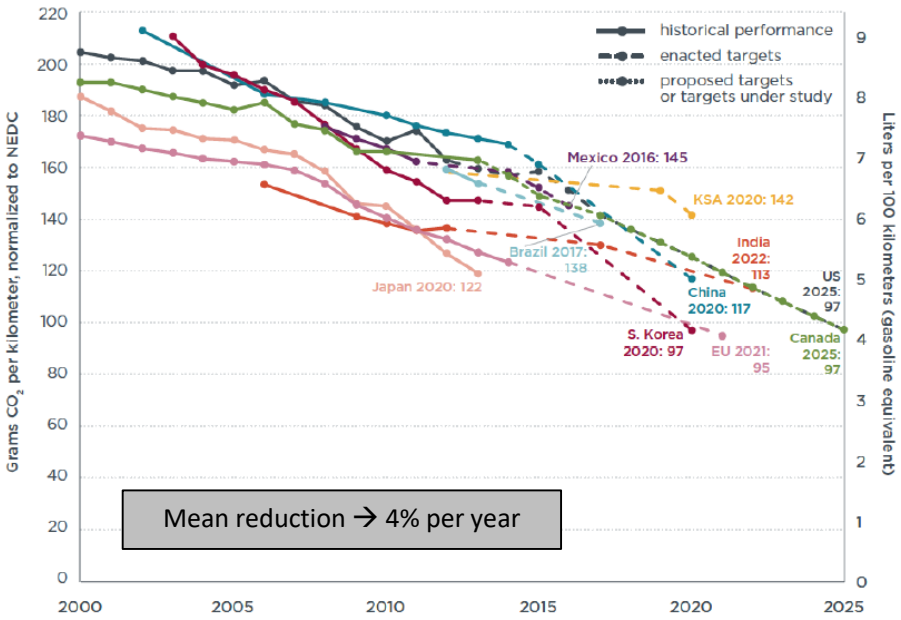
Local impact

Emission	%weight
CO	0,6
THC	0,1
NOx	0,1
Particle matter	0,1
Not regulated	

Gas-Only Internal Combustion Engines

Global impact: Green House Gases

Passenger car CO_2 emissions and fuel consumption, normalized to NEDC



icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

"Road to efficiency" workshop Brussels, June 9, 2016

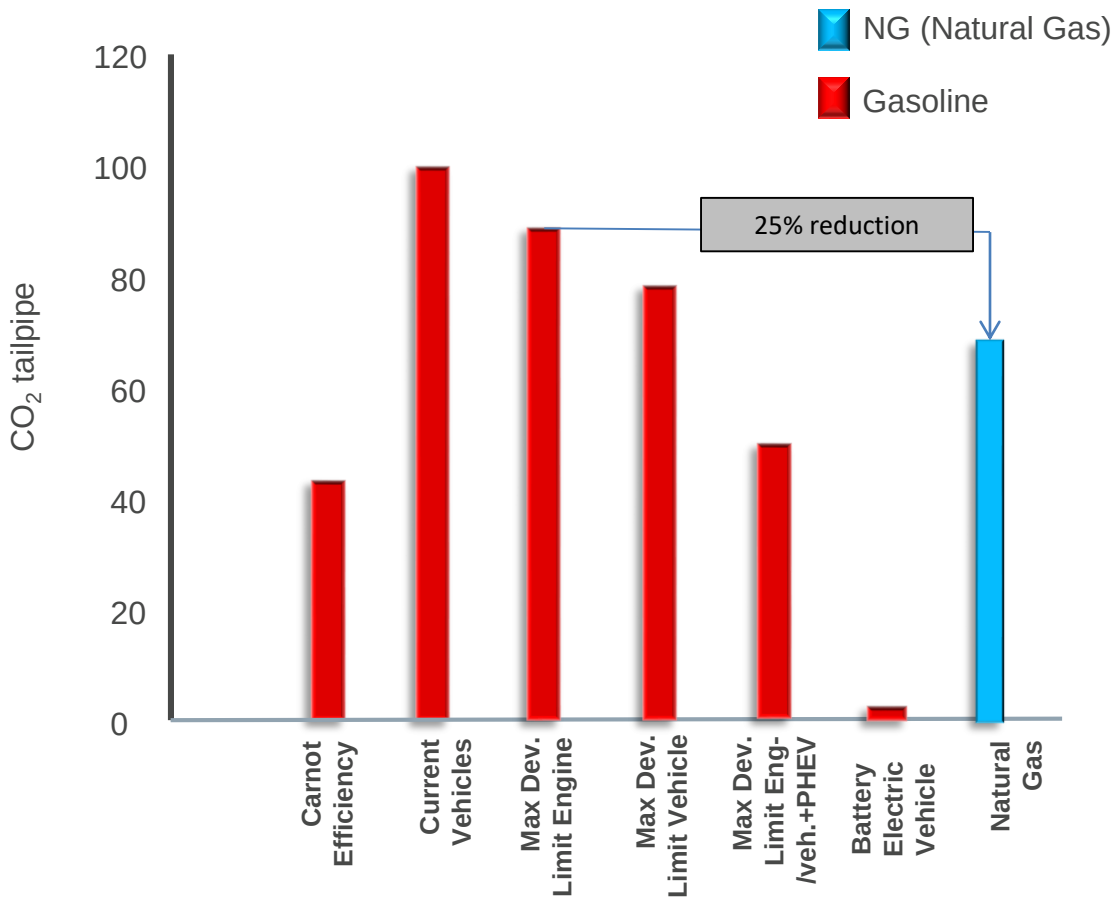
Engine efficiency ~ 30%

Vehicle demand energy

CO_2 is the main GHG. For a given fuel, the CO_2 quantity emitted depends on engine efficiency and vehicle characteristics (weight, rolling resistance, aerodynamics)

Gas-Only Internal Combustion Engines

CO_2 reduction walk



Alternative Low Carbon Fuels

The lowest carbon content fuel, the lowest the CO_2 produced

NG shows the best reduction

Gas-Only Internal Combustion Engines

A pragmatic answer: methane / natural gas

- CNG reserves greater than oil
- Lowest fuel costs & total cost of ownership
- Fossil CNG: up to 25% TtW CO2 reduction vs. gasoline with dedicated CNG cars
- Bio-Methane: already available as 2nd generation biofuel (~ 80% less WtW CO_2)
- Power to Gas Methane: ~ 95% less WtW CO_2

Right fuel for internal combustion engines

1) High knock resistant (RON > 120)

2) Ideal fuel for boosting and downsizing

3) High compression ratio enabler for efficiency improvement and further CO2 reduction

4) High boost pressure enabler (higher downsizing potential) for efficiency improvement by use of smaller engine architecture

5) No soot

Gas-Only Internal Combustion Engines

Even if current CNG technology is mature, the goal for the next generation of engines is to develop a technology exploiting all CNG benefits without drawbacks:

GasOn targets

- *Reduce drastically CO2 emissions (20%) vs current CNG technology*
- *Remove performance gap to achieve gasoline-like target*
- *Enhance engine efficiency facing post 2020 CO_2 challenges by means of innovative technologies (synergic effects)*
- *Achieve gasoline-like vehicle driving range in CNG mode*
- *Mitigate noxious emissions on real driving missions (post Euro6d compliance)*

Main figures

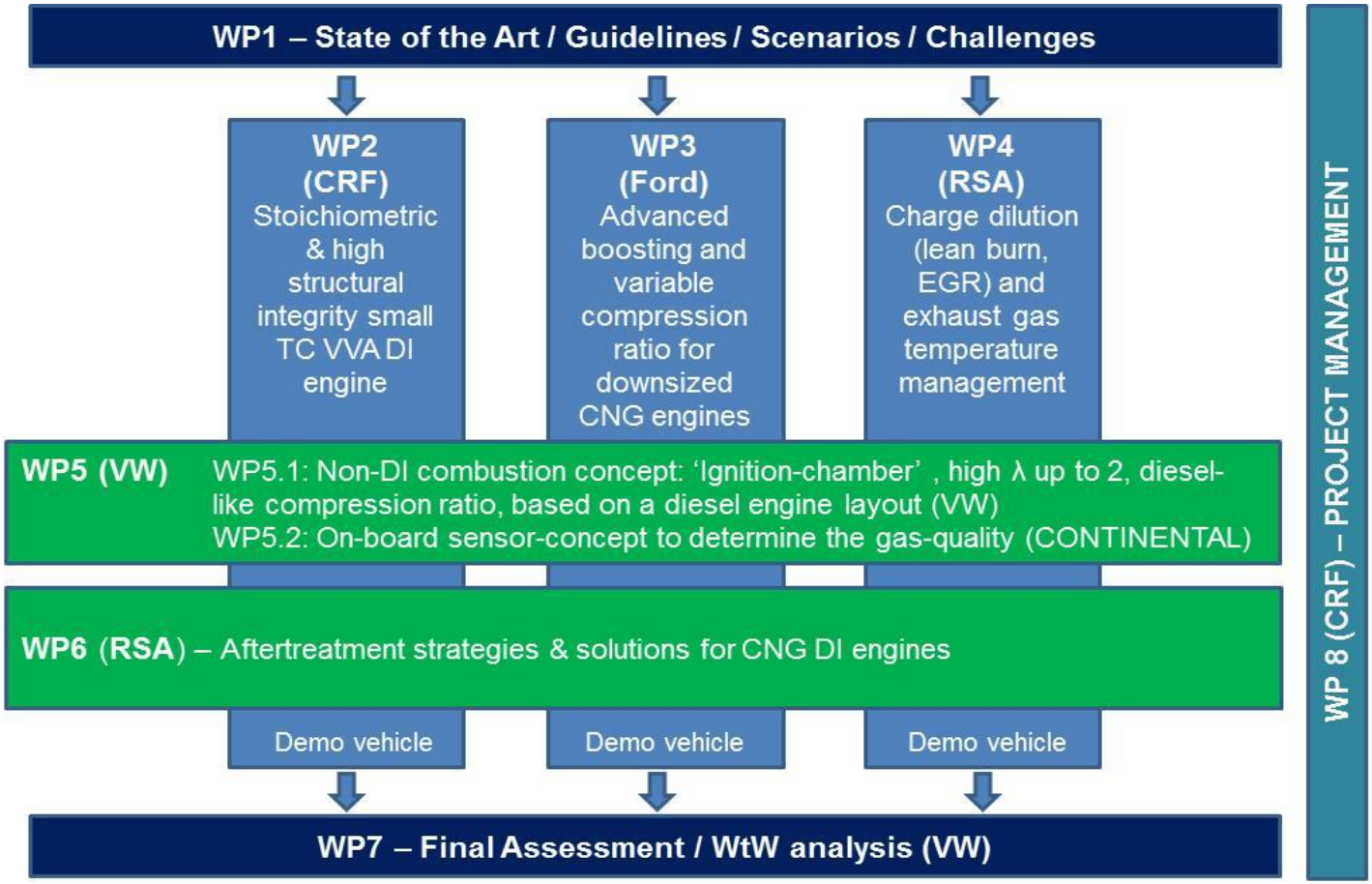
1. Acronym: GasOn
2. Title: Gas-Only Internal Combustion Engines
3. Number 652816
4. Topic: H2020 GV-3-2014 Future natural gas powertrains and components for cars and vans
5. Start Date: 1st of May 2015 (48 months)
6. Website: www.gason.eu

Overall project cost : **23 391 978 €**
Project grant : **16 704 978 €**

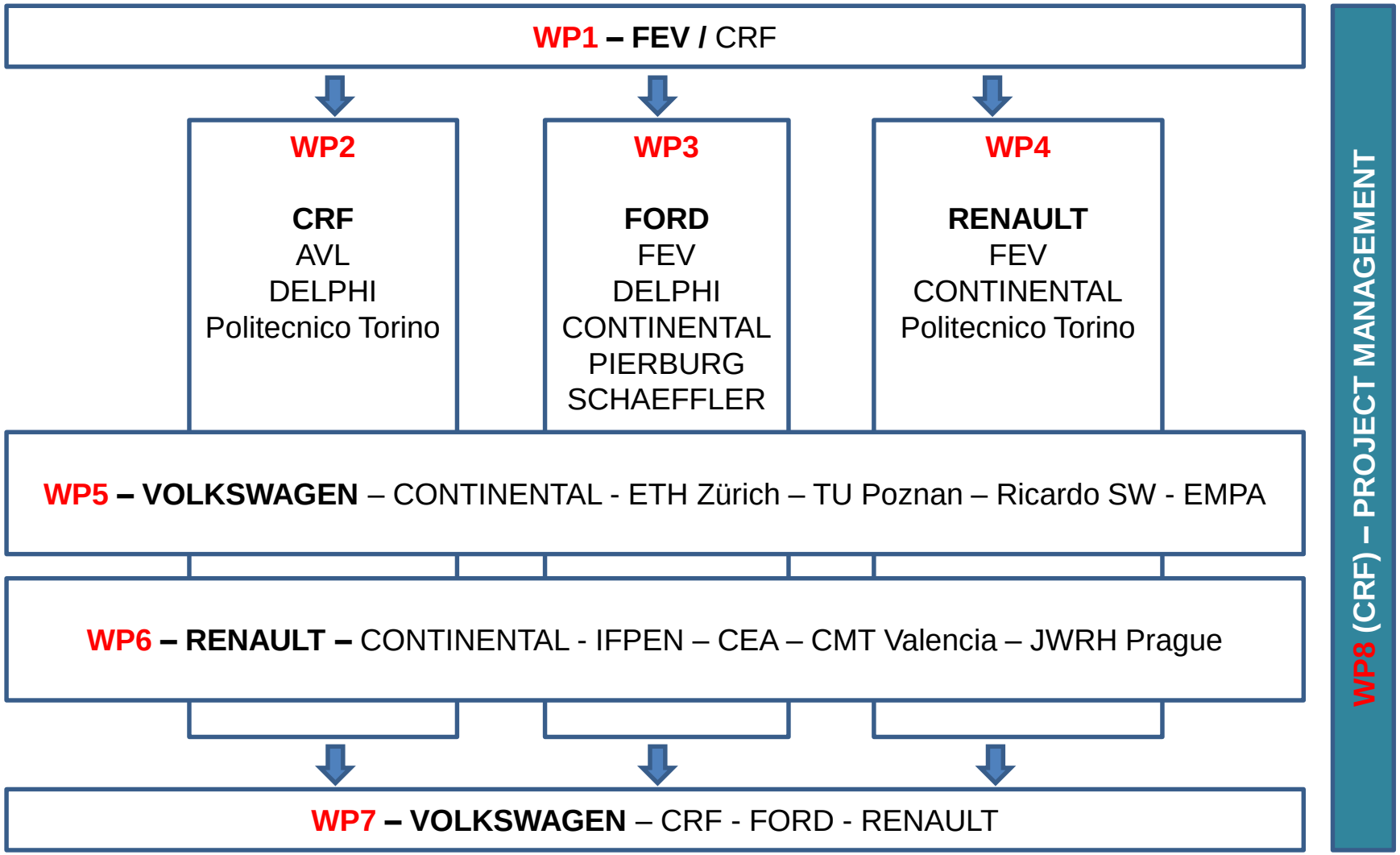
Consortium


CRF
CENTRO RICERCHE FIAT
Ford
RENAULT
FEV
AVL
ifp Energies nouvelles
cea
RICARDO
EMPA
Materials Science & Technology
Delphi Technologies
SCHAEFFLER
LuK
INA
FAG
Continental
PIERBURG
POLITECNICO DI TORINO
VALENCIA
ETH zürich
POZNAN UNIVERSITY OF TECHNOLOGY
CZECH TECHNICAL UNIVERSITY IN PRAGUE

Project structure



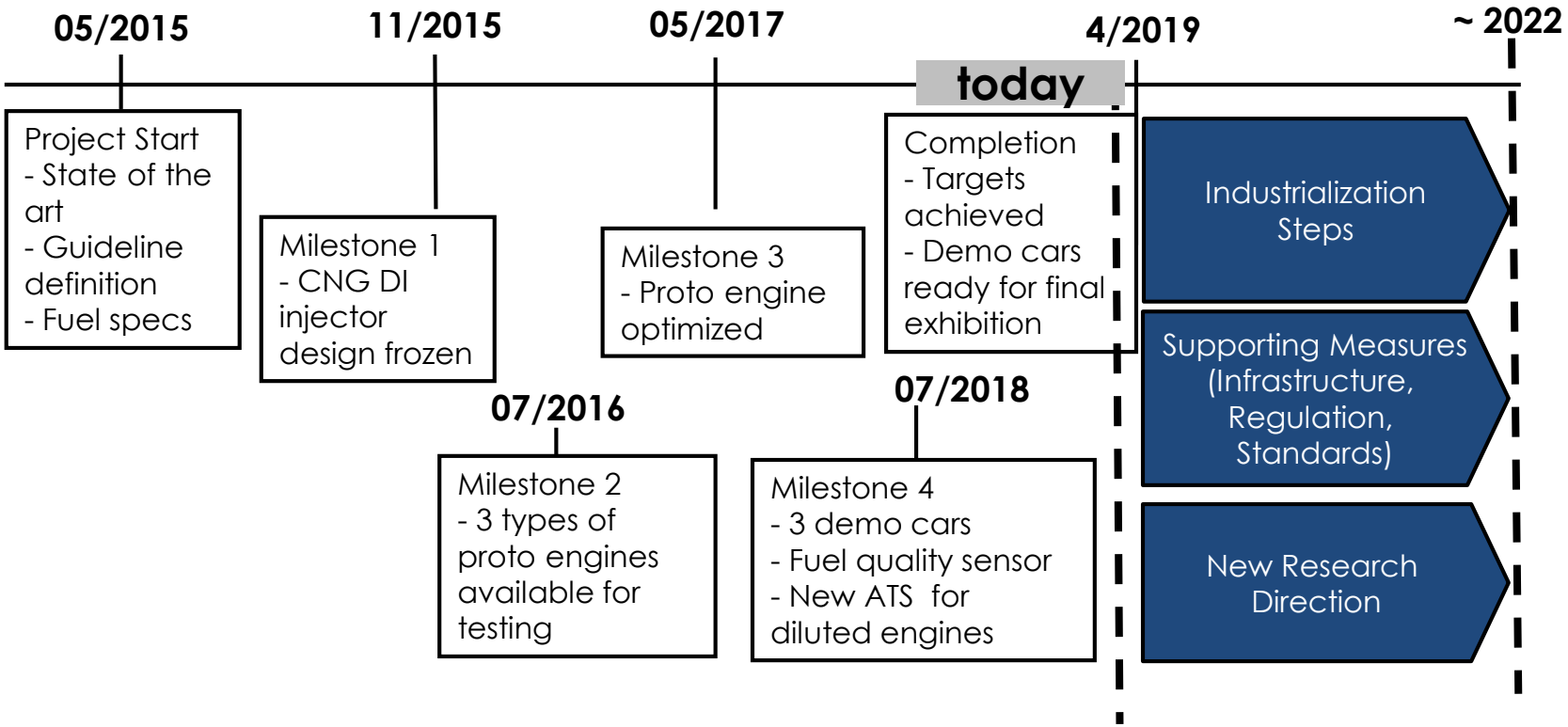
Gas-Only Internal Combustion Engines



Gas-Only Internal Combustion Engines

GHG Reduction Technology	Enabling Technology	Estimated GHG reduction range NEDC cycle		
		WP2 (CRF)	WP3 (Ford)	WP4 (RSA)
Downsizing and Extennal EGR benefit	Advanced Boosting	6 … 8%	10…12 %	5 … 8%
	CNG Direct Injection (CNG DI)			
Compression Ratio Increase	High Peak Pressure Capable Engine Architecture	3… 4%	1… 3%	3 … 4 %
	Variable compression ratio (VCR)	na		na
Dethrottling and/or advanced air management	Advanced Variable Valve Actuation	3…6%	2 … 3%	4 … 5%
	Charge Dilution	na	na	
CNG system weight reduction with downspeeding and further vehicle measures	Light Weight CNG Tank System	3 … 4%	5 … 7%	4 .. 6 %
	Downspeeding with longer final drive to trade performance (gained by weight reduction) against fuel economy			
	Vehicle frictions/aerodynamics	na	na	
	TOTAL	16 - 22 %	18 - 25 %	16 - 22 %

Project schedule

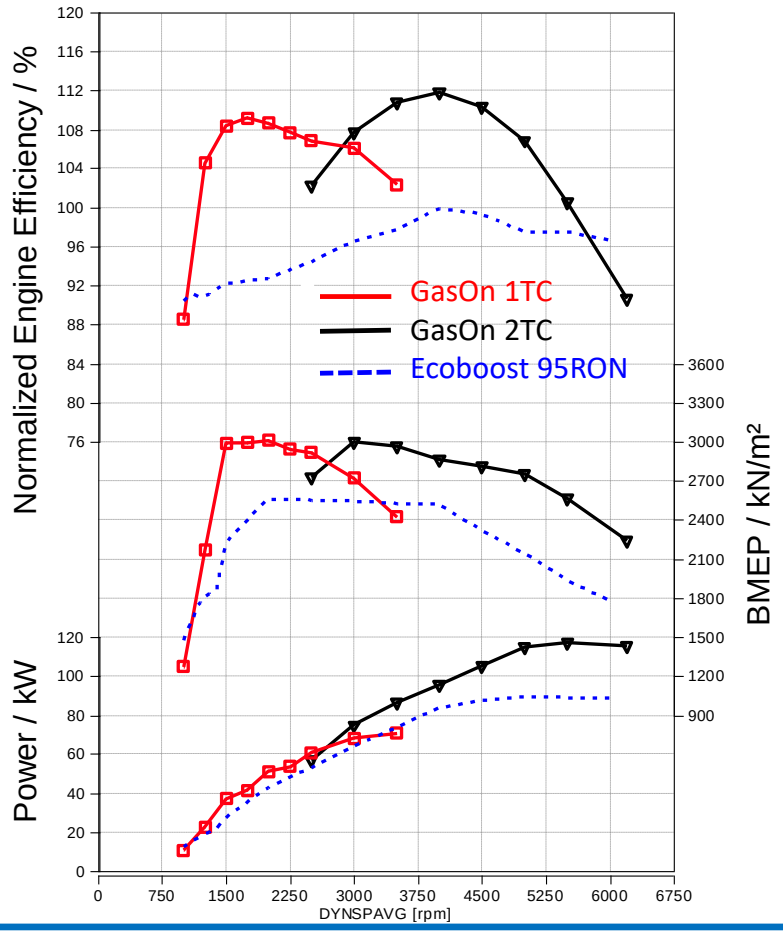


Facts in numbers

- Outstanding engine performance – BMEP = 30 bar
- Engine efficiency > 40% in a wide area
- CO2 reduction on RDE = 20%
- PN emissions one order of magnitude lower than limit w/o any aftertreatment
- Up to 650 km of driving range

Combustion System Development (Ford) - Power, Torque, Efficiency

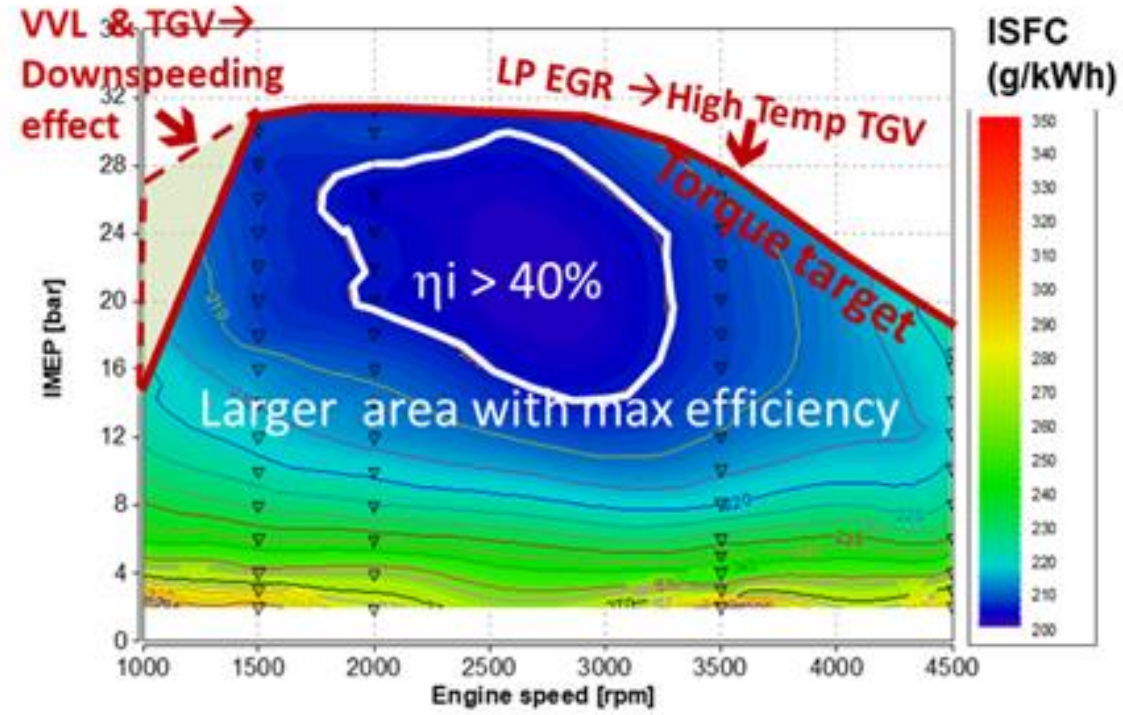
Power target (110 KW) overachieved (120 kW). BMEP target (30 bar) achieved.



Engine dyno test data:

- GasOn WOT efficiency (normalized on basis: gasoline 95 RON; 1.0l Ecoboost ®)
  - + 12 % peak efficiency (@ 4000 rpm)
  - + 16 % @ 1500 rpm
- Max BMEP 30bar @ 1500…3500 rpm → **target achieved**
- Peak Power 120kW (163hp) **overachieves target** of 110 kW (150 hp) **with Lambda 1 operation !**

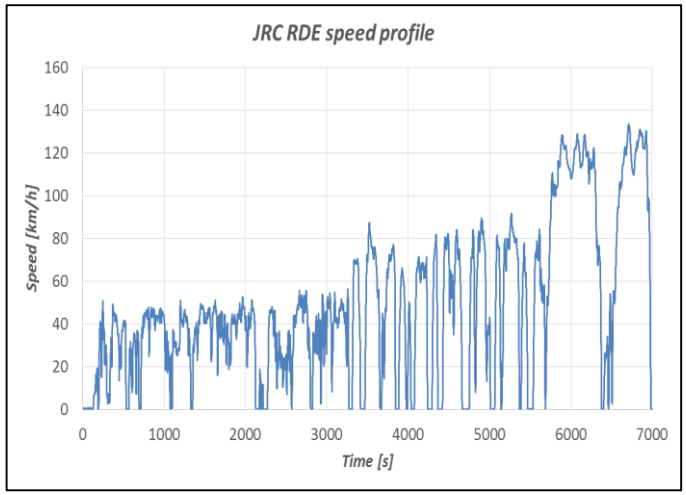
Engine efficiency enhancement due to synergic effects of innovative technologies



High Torque curve → Downspeeding effect → Long final drive for CO_2 and consumption reduction

JRC certification tests - Emission results

Real driving mission



RDE at JRC	CO (mg/km)	NOx (mg/km)	PN (1/km)	CO2 reduction**
Results with PEMS*	227	43	$2*10^{10}$	20%
Euro6d limit on WLTC	1000	60	$6*10^{11}$	-

* Mean values of 3 tests

** vs Fiat 500L Bifuel CNG PFI

First results from PN device developed on EU DownToTen project

WLTC cold – Jan. 2019 Metric 1/km		
23nm	10nm	4nm
$2.3*10^{10}$	$3.4*10^{10}$	$3.7*10^{10}$
$2.5*10^{10}$	$3.9*10^{10}$	$4.4*10^{10}$

Current PN devices for homologation detect particle diameter > 23 nm

Slight increase of PN with particle diameter down to 10 nm & 4 nm is measured but **absolute PN values are extremely low thanks to extreme clean fuel → CNG**

Demo Vehicle: Storage System Design & Installation (Ford)

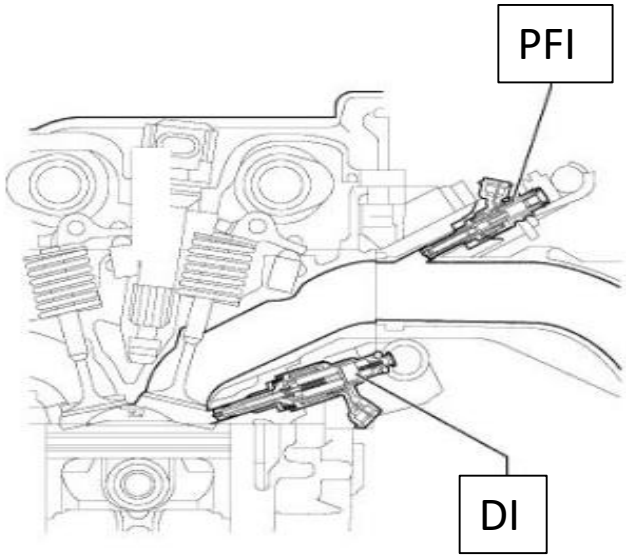
6 tanks installed: range approx. 650 km, 600 km range target overachieved

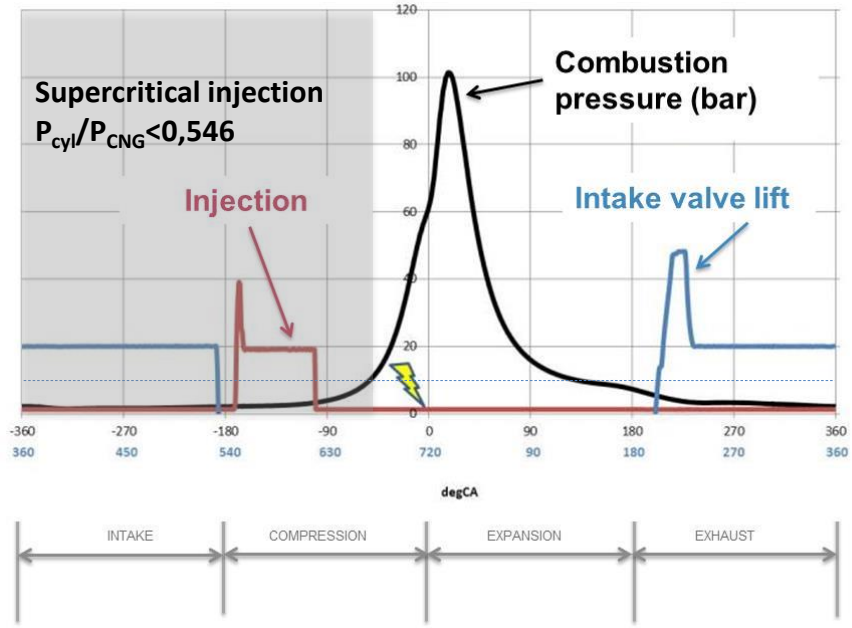
- 4 bottles underbody replace the original gasoline tank
- 1 bottle below trunk (vehicle body modified, spare wheel well removed).
- 6th mounted in the trunk behind 3rd seat row.
- 7-seater capability maintained

Outcomes

- New generation of CNG injection system
- New CNG combustion concepts
- Fuel quality sensor
- New storage layout complying with gasoline-like driving range

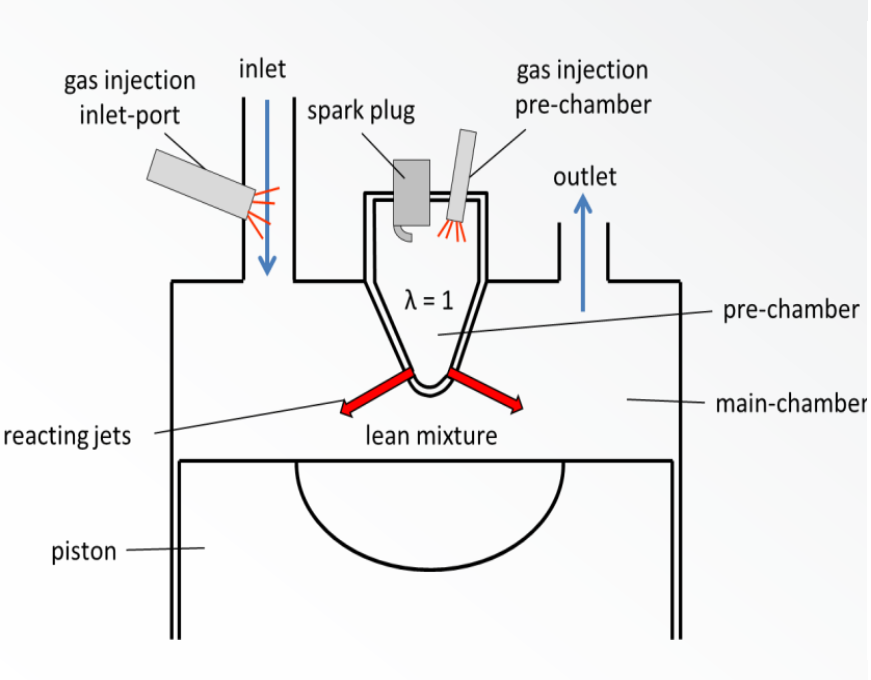
Gas-Only Internal Combustion Engines

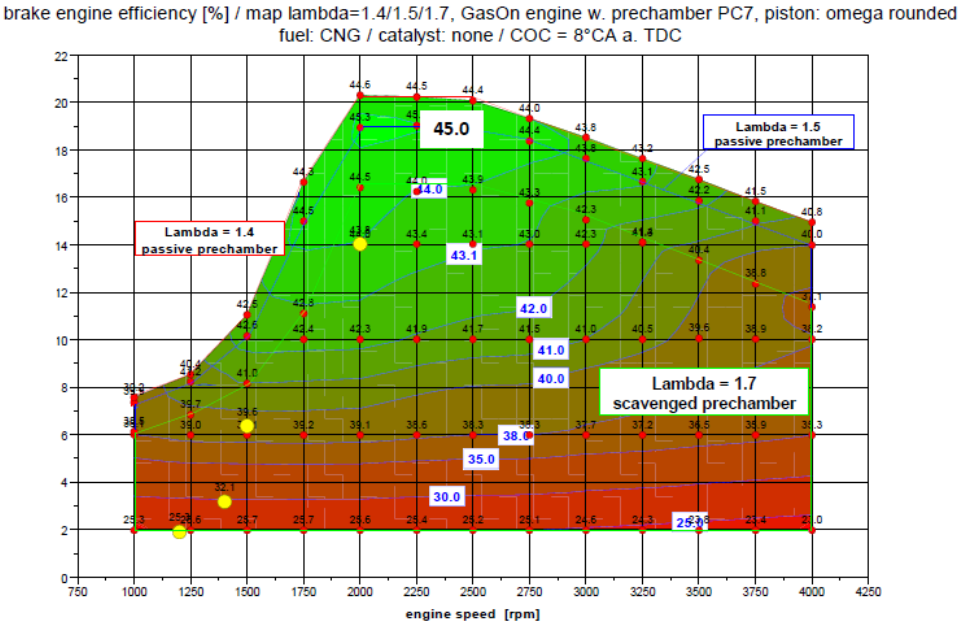




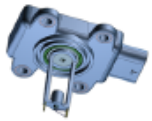
- Low pressure injection after intake valve closing (DI) to remove volumetric efficiency losses due to gaseous injection (PFI)
- Variable injection pressure system to comply with injection duration

Innovative combustion process





On-board sensor concept and module to detect the relevant gas quality parameters

Gas Quality relevant properties									
		 Optical Modul				 Thermal Module			
Criteria	Target Accuracy	Sample Output	Theoretical Accuracy	Results Testbench	Results Car Testing	Sample Output	Theoretical Accuracy	Results Testbench	Results Car Testing
Lower Caloric Value (MJ/m3)	2-4%	yes	<5%	+/- 4%	+/- 4%	yes	<+/- 5%	<+/- 10%	<+/- 10%
Methane Number	+/- 3%	no	with gas composition values deducible through algorithm			yes	<+/- 15%	<+/- 15%	<+/- 20%
Air Fuel Ratio	2- 4%	yes	—	+/- 6%	+/- 6%	no	<6%	—	—

The optical sensor will be the solution for further development and series production. It was possible to predict gas components, like Butane, Carbon Dioxide, Nitrogen and to calculate the Wobbe Index.

This on-board optical gas sensor will help also to increase the engine efficiency of all CNG light duty vehicles, through the possibility to set ignition timing for all gas qualities to maximum efficiency.

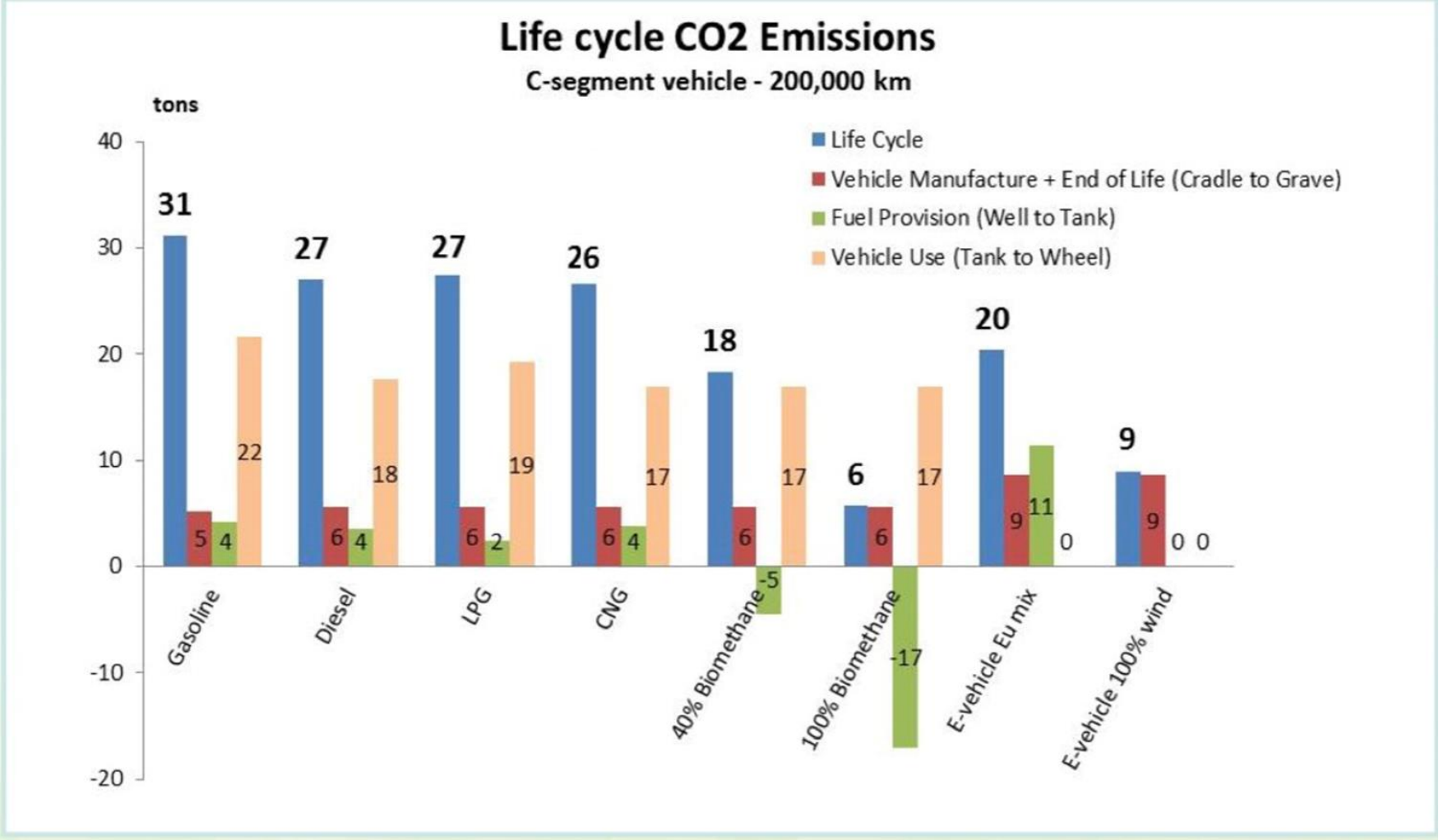
Further outcomes

- 60 dissemination actions (papers, workshops, conferences, etc.)
- 72 deliverable reports
- >10 innovative technologies applied on CNG engines
- 3 demo cars with different integrated solutions

Impacts

- New generation of extremely efficient and clean CNG engines
- Tank to Wheel Greenhouse gases (GHG) mitigation among 16% and 25% on NEDC cycle vs. current best in class
- Further GHG mitigation with the adoption of renewable methane (biomethane, e-gas, etc.) with zero WtW CO_2 impact
- Pragmatic and mature complementary solution to current mainstream able to mitigate GHG and noxious emission

Gas-Only Internal Combustion Engines



FCA elaboration of internal & JRC data presented at Zero CO_2 Mobility – FEV Conference – Aachen, Germany (November 9-10, 2017)

Conclusion

GasOn project demonstrated the high potential of CNG engines/vehicles as key pillar for current and future on road light duty transportation by means of innovative solutions	√
Gasoline-like performance and driving range, low noxious emissions and halved CO_2 vs current gasoline engines/vehicles are feasible and affordable now!!!	√
WtW approach enables the NG adoption as complementary automotive solution vs current mainstream	√
Infrastructure growth is a key element to enlarge CNG fleet in EU28 CNG overcame several issues not yet solved by mainstream	√