



Simon Reader

Engineering Director
MAHLE Powertrain Ltd

Sponsors



IHS Markit



Johnson Matthey
Inspiring science, enhancing life

trueform

Gasoline Engine Technology Outlook for Future Passenger Cars

Cenex – Low Carbon Vehicle Event

6th – 7th September 2017

Millbrook

Simon Reader

Engineering Director

MAHLE Powertrain Ltd Northampton, UK



Gasoline Engine Technology Outlook for Future Passenger Cars
Industry Mega-trends



Background – UN Convention on Climate Change 2015

- UN Convention on Climate Change 2015 (COP21), 197 countries agreed common climate policy targets
- Paris Agreement central aims
 - Strengthen global response to threat of climate change
 - Aim to keep global temperature rise this century well below 2°C

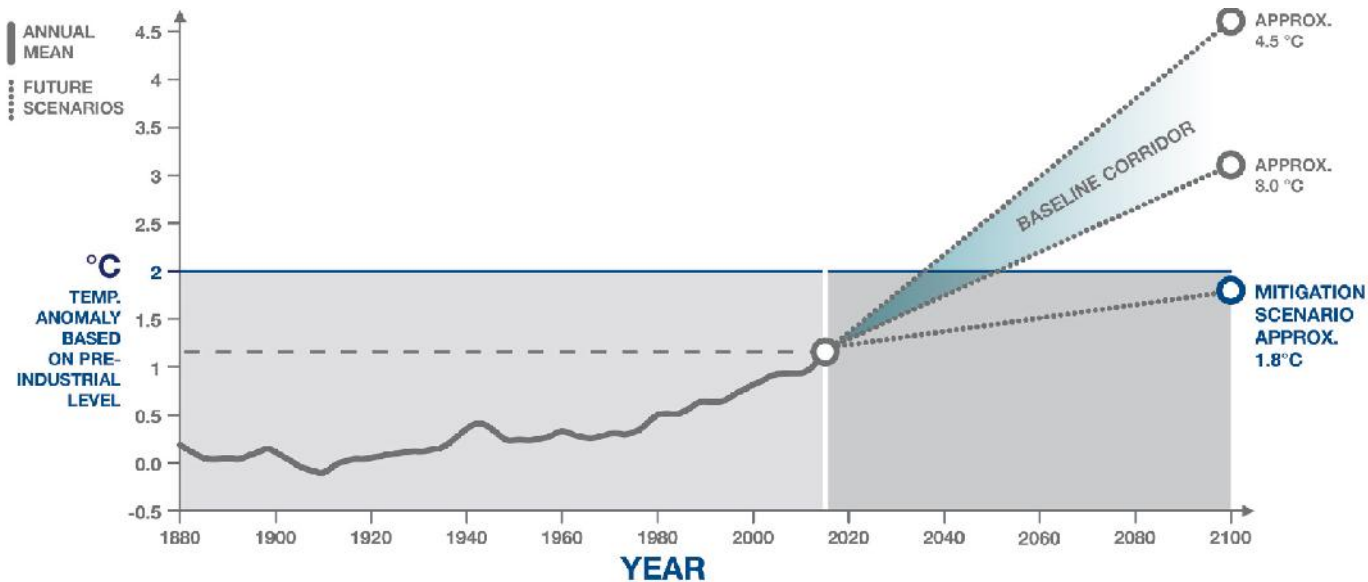


Sources:

- United Nations Framework Convention on Climate Change: Homepage.
- Dataset accessed 2017-03-24 at http://unfccc.int/paris_agreement/items/9485.php.

Background – Global Warming

- Estimation of global air surface temperatures suggests upward trend of over 1 °C

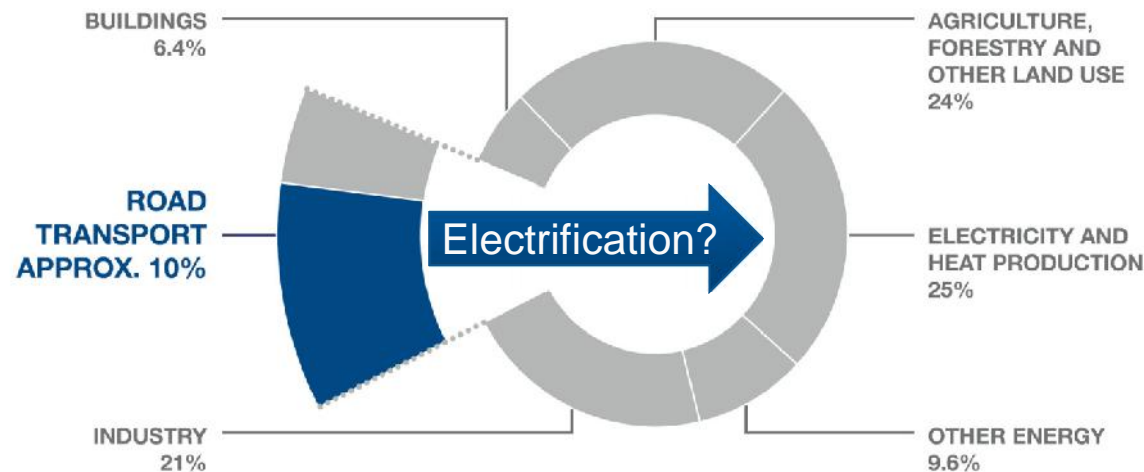


Sources:

- GISTEMP Team, 2017: GISS Surface Temperature Analysis (GISTEMP). NASA Goddard Institute for Space Studies. Dataset accessed 2017-03-24 at <https://data.giss.nasa.gov/gistemp/>.
- Hansen, J., R. Ruedy, M. Sato, and K. Lo, 2010: Global surface temperature change, Rev. Geophys., 48, RG4004, doi:10.1029/2010RG000345.
- IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. page 63.

Background – Contribution of the Transport Sector

- Transport sector accounts for around 14% of anthropogenic greenhouse gas emissions
 - Around 10% from road transport sector (commercial and passenger vehicles)
 - Growing fleet means transportation continues to play significant role over next decade

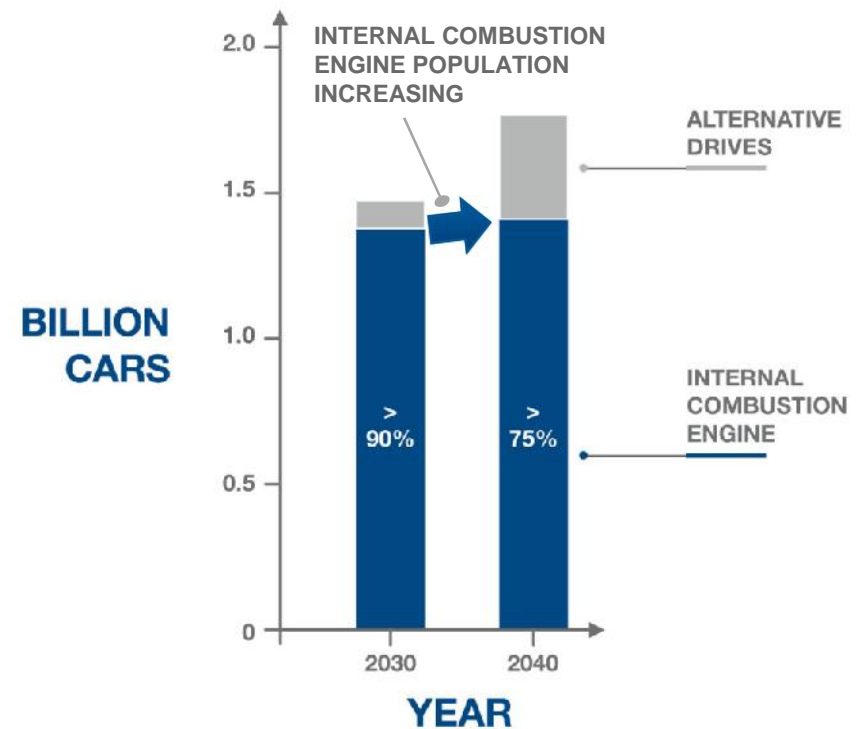


Sources:

- IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. page 47

Background – Global Passenger Car Fleet

- Most vehicles in actual global fleet will have an ICE beyond 2030
- Vehicles continue to contribute to transport sector CO₂ for many years after their manufacture
- Need to maximise potential of the ICE

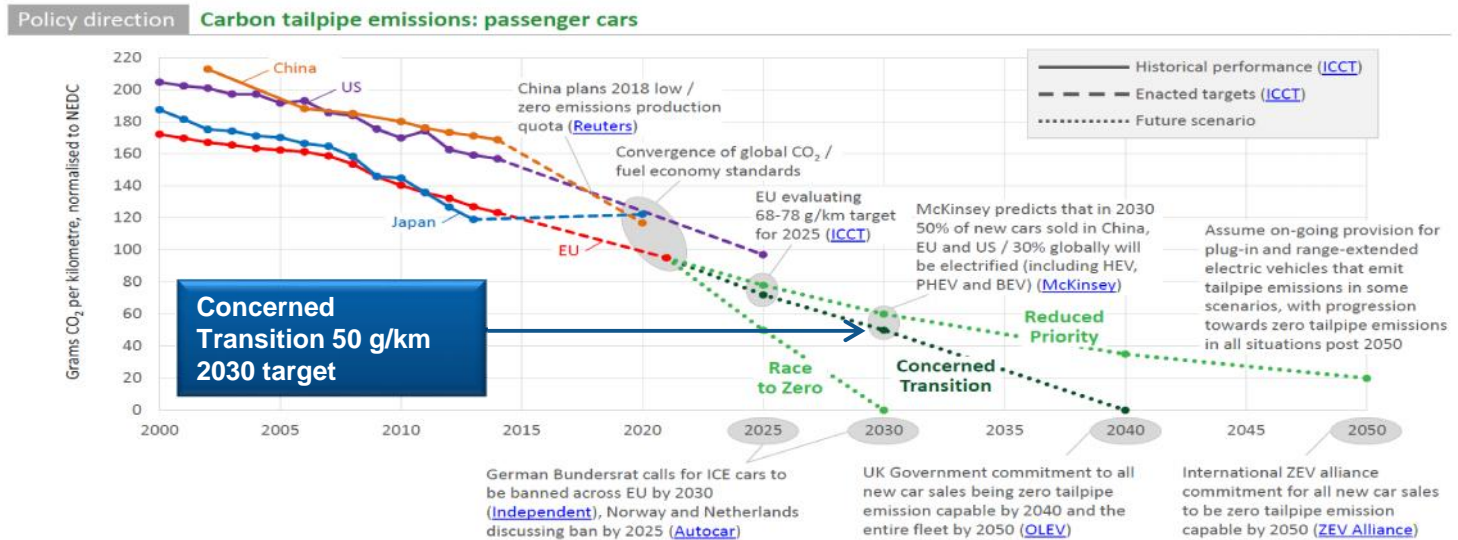


Gasoline Engine Technology Outlook for Future Passenger Cars

Future Legislation Outlook - Automotive Council UK Outlook



The scenarios explore different glide paths towards 100% of new car sales being zero tailpipe emission (capable) across the major markets



- By 2030, the upper limit for passenger car CO₂ emissions will be 50 g/km according to the Automotive Council UK's "concerned transition scenario"

Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future



Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future



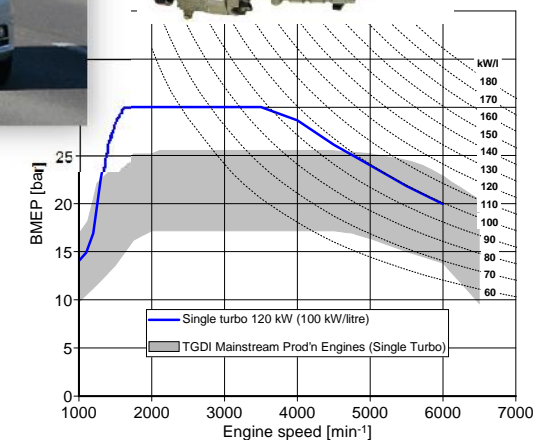
Gasoline Engine Technology Outlook for Future Passenger Cars

MAHLE Downsizing Demonstrator Engine

MAHLE

Powertrain

- MAHLE technology demonstrator engine ran in 2007
 - Achieved **100 kW/litre** (single turbo)
- Continuous development platform
 - Increased high & part load efficiency
 - Thermal management
 - Alternative fuels, ...
- **24% CO₂ reduction** on NEDC
 - 30% total reduction with stop-start

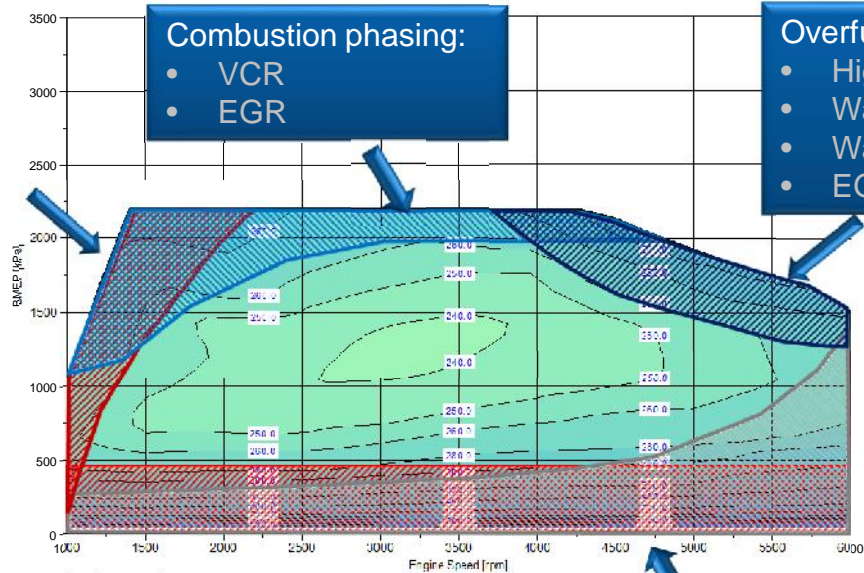


Powertrain Efficiency Losses - Key Opportunities

- Heat losses:**
- Bore/stroke ratio
 - Thermal coatings
 - Lean combustion

- Combustion phasing:**
- VCR
 - EGR

- Overfuelling (component protection):**
- High temperature turbine
 - Water injection
 - Water cooled exhaust manifold
 - EGR



Other Possibilities

- Fast warm-up
- Alternative fuels
 - Low CO₂
 - Higher RON for high loads
- Hybridisation
 - Recuperation
 - Load point shifting

- Pumping/throttling losses:**
- Downsizing
 - Variable valvetrain
 - Lean combustion

Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future

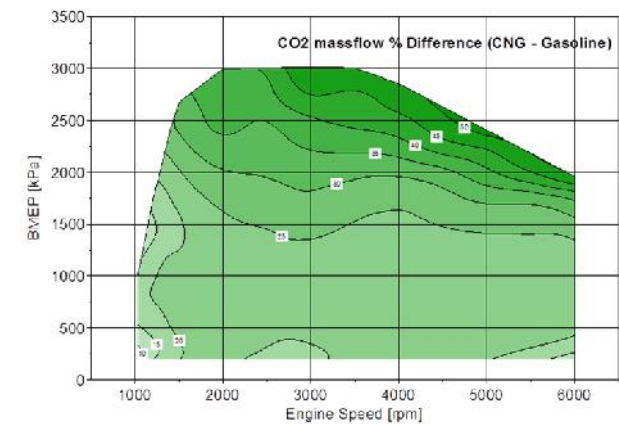


MAHLE Downsizing Demonstrator Engine – CNG Optimised

- CNG optimised MAHLE technology demonstrator
- Cylinder and power cell unit components and valves redesigned to perform at 180 bar peak cylinder pressure
- VTG turbocharger operating at up to 260k rev/min
- High downsizing of a CNG engine with very low emissions
- **18-24% CO₂ reduction** compared to gasoline
 - Even on aggressive and real world cycles
 - Up to 50% lower CO₂ at maximum power



- 980°C Max turbine inlet temperature



Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future

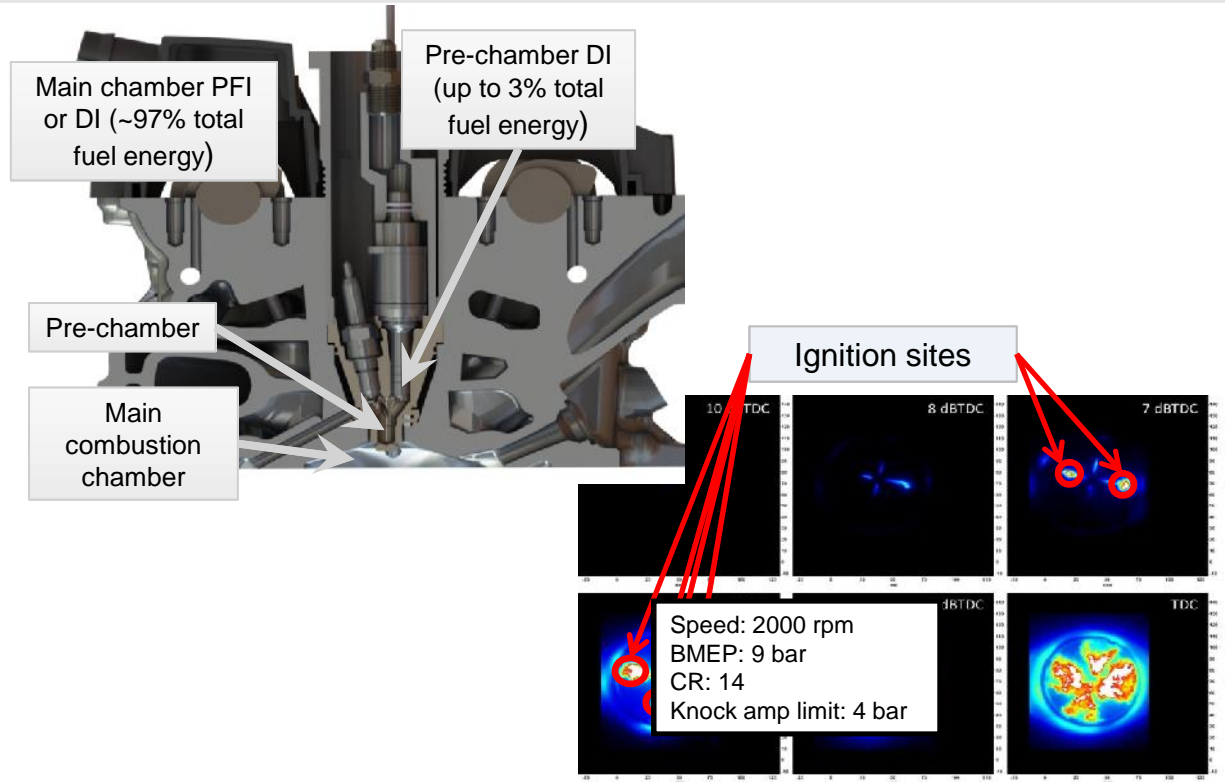


Gasoline Engine Technology Outlook for Future Passenger Cars

Operational Benefits of MAHLE Jet Ignition®



- Advantages:
 - Multiple ignition sites
 - Elevated ignition energy
 - Faster burn rates
- Knock mitigation
 - Combustion phasing benefit compared to spark
 - Elevated CR
- Superior combustion stability enables ultra-lean operation



Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future



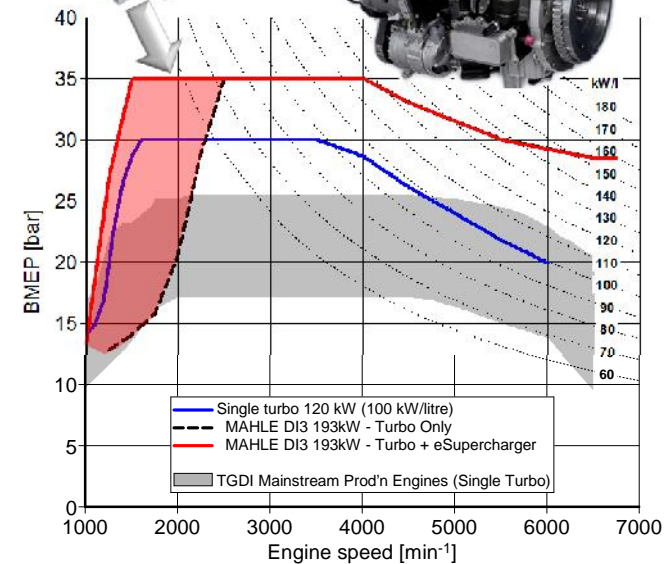
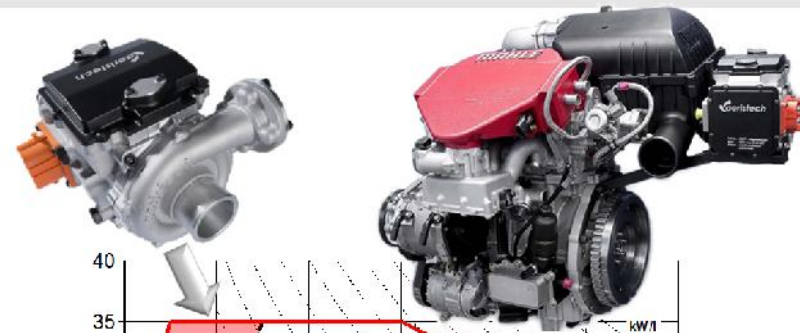
Gasoline Engine Technology Outlook for Future Passenger Cars

MAHLE

Powertrain

MAHLE eSupercharged Downsizing Demonstrator Engine

- MAHLE eSupercharged technology demonstrator engine ran in 2014
 - Achieved **160 kW/litre** (turbo + eSupercharger)
- Aeristech eSupercharger
 - Continuous boosting capability at 5 kW operation
 - High speed operation (120,000 rpm)
 - Enables excellent transient response



Main Dimensions and Engine Data		
Configuration	-	In-line 3 Cylinder
Capacity	cm ³	1200
Bore	mm	83.0
Stroke	mm	73.9
Compression Ratio	-	9.3 : 1
Boosting	-	BMTS turbo + Aeristech eSupercharger
Peak Power	kW	193 (6750 min ⁻¹)
Specific Power	kW/litre	160 (6750 min ⁻¹)
BMEP	bar	35 (1500-4000 min ⁻¹)

Advanced Engine Technologies for 200 kW/litre and Beyond

MAHLE eSupercharged Downsizing Demonstrator Vehicle

MAHLE
Powertrain

- 160 kW/l Demonstrator vehicle built in 2016 to showcase the engine
- **25% CO₂ reduction** on NEDC
 - 15% reduction from engine downsizing (c.f. 2.0 litre TGDl baseline)
 - Remaining benefit through 48V hybridisation and user defined shift-strategy



Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future



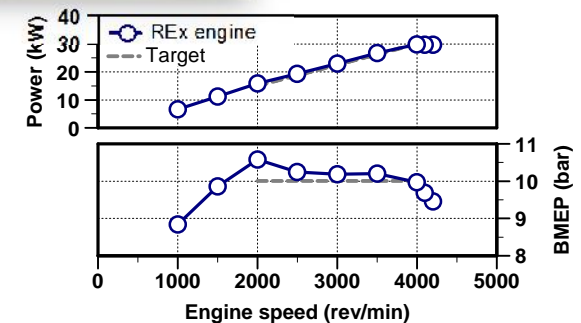
Gasoline Engine Technology Outlook for Future Passenger Cars

MAHLE

Powertrain

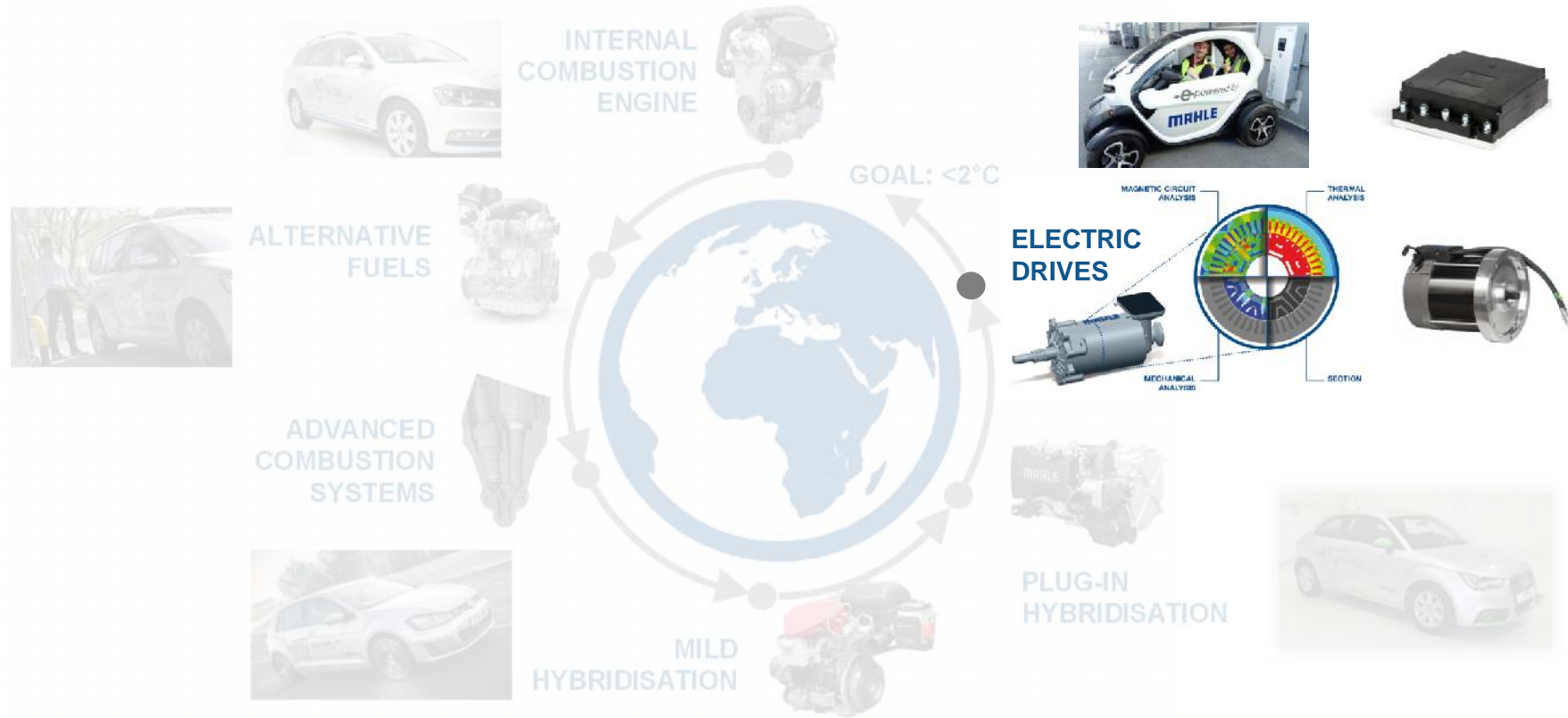
MAHLE Range Extender Engine

- Clean sheet of paper design optimised for low cost, light weight and compactness
- Range of power outputs achieved through common family architecture 30 – 50kW
- Flexible installation angle
- B-Segment Demonstrator Vehicle built in 2012 to showcase the engine
- Total range 500 km (70 km pure electric range)
- 42 g/km CO₂ Tail-pipe emissions for NEDC
- Charge sustaining speed of 120 km/h
- Dynamic performance comparable to baseline vehicle



Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future



MAHLE – Electrification Product Portfolio

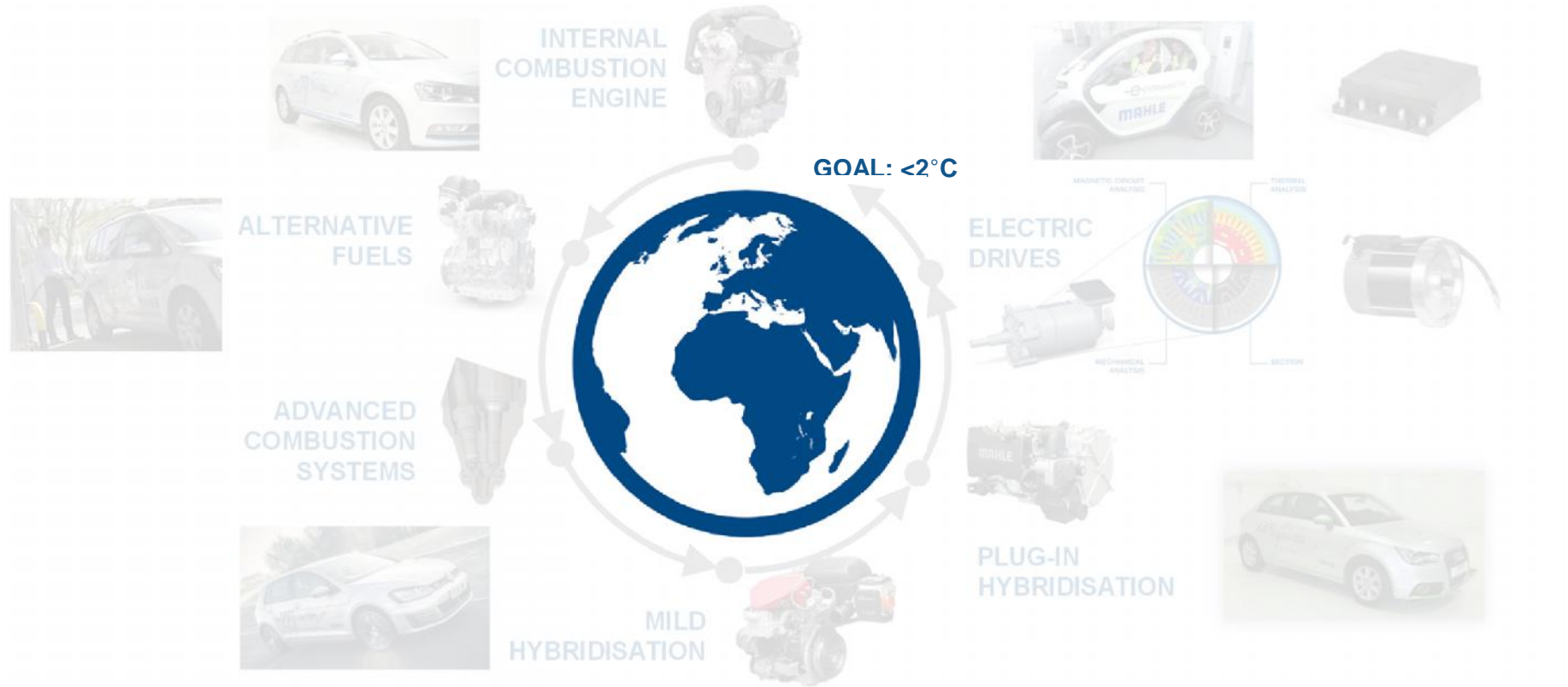


- Electric Machines:
 - Starter Motors, Alternators, Electric Motors and Electronics, Drive Systems, Electrically Driven Auxiliaries
- Electric Systems and Ancillaries:
 - Climatic & HVAC components, DC & BLDC motor control, Sensors, EV power electronics components



Gasoline Engine Technology Outlook for Future Passenger Cars

Road Map for the Future



Conclusions

Future fuel consumption targets are challenging

INTERNAL COMBUSTION ENGINE



Advanced engine technology still able to yield significant benefits

GOAL: <2°C

ALTERNATIVE FUELS

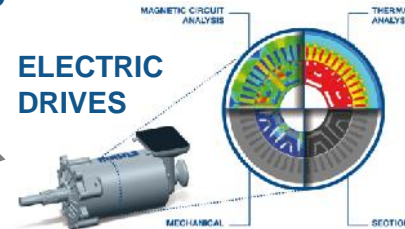


Alternative fuels should play a significant part in the future

ADVANCED COMBUSTION SYSTEMS



ELECTRIC DRIVES



Electric drive gives some benefits

Energy recovery is important to enable best efficiency

MILD HYBRIDISATION

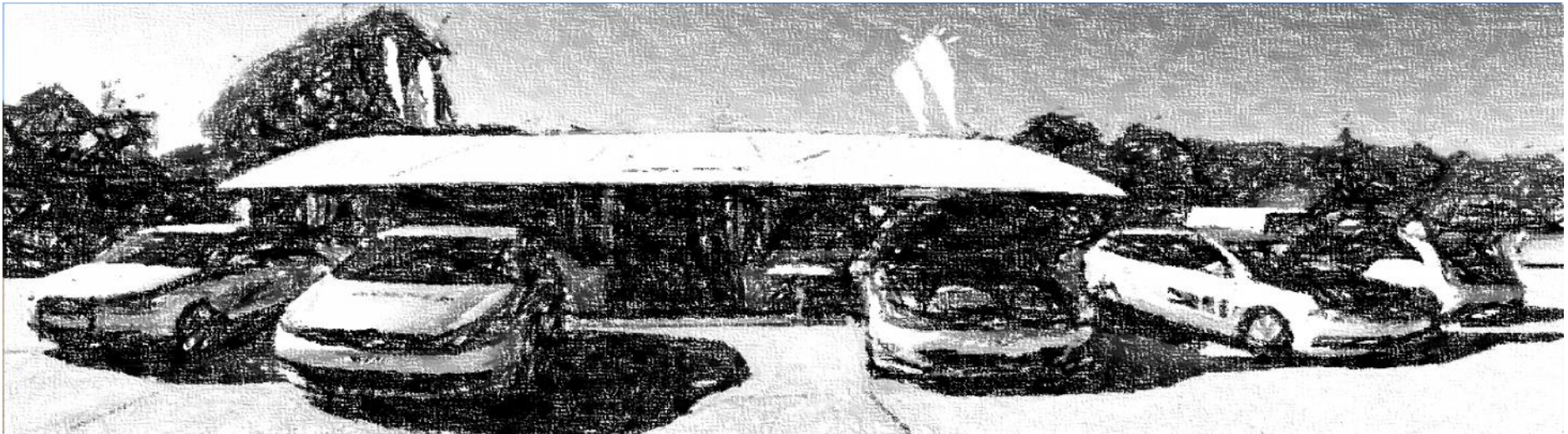


PLUG-IN HYBRIDISATION



Hybridisation is key to meeting future CO₂ targets

THANK YOU





cenex