Traction motors & generators roadmap (<40kW)

Permanent Magnet
- Development of lighter weight induction machines

Induction

PM content reduction

Hybrid motors

Switched reluctance
- Advanced electronics and control provides step change

Synchronous reluctance

Multistage

48V Micro/mild hybrid
- Integrated electric powertrain & vehicle cooling

Thermal management
- Modular single speed
- Integrated single speed traction motion gearbox

Traction motion gearbox
- Multispeed torque cut gear shifts
- Multispeed power shift

Wheel motors: geared drive

Wheel motors: direct drive

Prototype
Production

Source: Automotive Council Technology Group 2013
Traction motor & generator roadmap (100kW+)

- Permanent magnet
- Induction
- Hybrid motors
- Switched reluctance
- Synchronous reluctance
- Multistage
- Thermal management
- Modular single speed
- Integrated electric powertrain & vehicle cooling
- Traction motion gearbox
- Multispeed torque cut gear shifts
- Multispeed power shift
- Wheel motors: geared drive
- Wheel motors: direct drive
- Prototype
- Production

Source: Automotive Council Technology Group 2013
Power train (ICE) technology roadmap

Enabling Technologies
- Fuel injection system optimisation
- Increased charge air boost efficiency/range
- High efficiency low NOx combustion concepts
- Reduced combustion heat losses
- Mech. turbocompound
- Electrical turbocompound
- Organic rankine cycles
- Split/recuperated cycle
- Lower mechanical friction (coatings/bearings/etc)
- Downsizing & boosting technologies
- Downspeeding for lower friction
- Variable power ancillaries
- Low thermal inertia/fast warm-up systems
- Thermo-electric generators
- Integrated electrification & energy recovery technologies
- Flexible valve trains (timing/lift/actuation)
- Model Based Control
- Real Time Models
- Closed loop/feed back tuning
- Integrated PM and NOx emissions control systems
- Active charge thermal management/control
- Advanced/new lightweight materials
- Flexible/fast response boost
- Thermal energy storage/fast warm-up

Systems Efficiency
- Air Quality
- Euro 5 2009
- Euro 6 2014
- Euro 7 2019?

Thermal Efficiency
- 2015
- 2020
- 2025
- 2030

EU Fleet Average CO2 Targets (g/km)
- 130
- 95
- TBD

Source: Automotive Council Technology Group 2013
Commercial and off-road technology roadmap

**Drivers**

- LD Van $\text{CO}_2$ Regulation
- Possible HD/MD $\text{CO}_2$ Regulation
- UK $\text{CO}_2$ Target

**Breakthrough in energy storage**

- H$_2$ infrastructure
- Fuel cell vehicles
- Fuel Cell APUs
- Demos
- Plug in hybrid
- Full hybrid
- Micro/Mild hybrid

**Intelligent vehicles logistics – operational efficiency (On & Off-highway)**

- Advanced highway vehicle aerodynamics/selective lightweighting

**CO$_2$ and GHG reduction**

- GHG - greenhouse gas
- "Zero" Air Quality Impact

**Air Quality Improvements**

- Carbon composite BIW
- -290kg
- Carbon composite bolt on panels
- -200kg
- Titanium LW transmission & driveline
- -435kg
- Metal matrix composites
- -425kg
- Hybrid materials
- -200kg

**Mass Reduction**

- Aluminium (BIW, bolt-on panels, chassis)
- Lightweight roof systems
- Lightweight seat systems
- Steel (UHSS, tube hydroforming, hot stamping)
- Lightweight seat systems
- Lightweight structural plastics
- Sheet moulding compound panel
- Aluminium thin-wall HPDC casting
- -120kg
- Alternative lightweight vehicle architectures
- Numerically intensive computing & CAE multi-physics optimisation
- Real world data (RWD) & structural health monitoring

Source: Automotive Council Technology Group 2012
Lightweight vehicle and power train roadmap

Mass Reduction (on 2012 mass)
- Aluminium (BIW, bolt-on panels, chassis)
  - Lightweight seat systems
  - Sheet moulding compound panel
  - Lightweight structural plastics
  - Steel (UHSS, tube hydroforming, hot stamping)
  - Aluminium thin-wall HPDC casting

Carbon composite BIW
- Carbon composite bolt on panels
- Alternative lightweight vehicle architectures
- Numerically intensive computing & CAE multi-physics optimisation
- Real world data (RWD) & structural health monitoring

EU Fleet Average CO₂ Targets (g/km)
- 2010: 130
- 2015: 95
- 2020: TBD

Source: Automotive Council Technology Group 2013
Energy storage Echem Tech roadmap

Source: Automotive Council Technology Group 2013
Intelligent mobility technology roadmap

**Autonomous vehicles**
- Safety critical systems
- Multi-modal journey planning & optimisation systems
  - Value: Congestion & pollution reduction
  - Increased mobility
  - Intelligent mobility objectives delivered

**Recognition & control algorithms**
- On-board sensors & actuators
- V2V communications
  - Value: Cost reductions (service & maintenance)
  - Safety improvements

**HMI**
- V2I communications
- A-V Systems
  - Value: Communication & Entertainment
  - Business & Commercial Benefit

**Processing**
- Fast
- Faster
- Even faster

**Storage**
- Local
- Mixed
- Cloud

**Transfer**
- 3G
- 4G
- 5G

Source: Automotive Council Technology Group 2013
The motorsport technology roadmap focuses on chasing *integrated* performance efficiently with cost-effective CO₂ reduction.

### High Level Technology Roadmap for Motorsport

**Drivers**
- Market engagement - spectators, customers (especially ageing demographic), the show, service industry

**Performance:**
- Reduce CO₂ and increase kW/l (engine) and Nm/kg (transmission) for efficiency and "green" image

**Safety**
- Low friction design and lubrication
- Cost effective fast-shifting semi-autos
- Materials, structures and manufacturing processes

**Propulsion**
- Fuel systems: Direct injection, alternative fuels, fuel flow limits
- Advanced boosting systems
- Energy recovery/split cycle/fuel cells

**Transmission/driveline**
- Cost effective fast-shifting semi-autos
- Materials, structures and manufacturing processes
- Energy recovery/split cycle/fuel cells

**Vehicle**
- Low friction design and lubrication
- Enclosed cockpits, covered wheels
- Brake electrification (linked to energy storage)

**Energy management/infrastructure**
- Kinetic energy recovery
- Energy storage (on-board/remote batteries, flywheels, ultra-caps, hydraulic ... )
- Waste heat recovery
- Battery/system charging/safety/management at venue

**ITS**
- Telemetry, data/information feed direct to consumers

Source: Ricardo analysis, interviews with Williams F1, Force India, Ford Racing, Alcon, Lola and Dallara
Bus technology roadmap

Breakthrough in energy storage

- Niche EVs
- Mainstream EVs
- Fuel cell vehicles
- Plug in hybrid
- Mild/mild hybrid
- Full hybrid
- IC Engine efficiency improvements
- Waste heat recovery
- Advanced thermodynamic cycles
- Biofuels
- Sustainable liquid/gaseous fuels
- Powertrain efficiency improvements/ancillary electrification
- Reducing body energy consumption
- CO₂ neutral improved bus desirability (driver/passenger)
- Intelligent vehicles logistics – operational efficiency
- Reducing rolling resistance/lightweighting

Drivers
- CO₂ reductions limited by emissions regulation
- LD Van CO₂ Regulation
- Possible HD/MD CO₂ Regulation
- “Zero” Air Quality Impact
- Air Quality Improvement
- UK CO₂ Target
- CO₂ and GHG reduction
- GHG = greenhouse gas