T E C | Turquoise Engineering Consulting

Emerging engine and powertrain technologies

Professor Geoff Callow

EEVF 2007

Turquoise Engineering Consulting (TEC)

- **Provider of independent technical consulting & due diligence services:**
  - Pre-investment due diligence
  - Preparation of independent technical reports for fundraising companies
  - Technical due diligence for mergers and acquisitions
  - Technical input to company valuations
  - Technical support for sector mapping and investment planning by funds and donors
  - Review of R&D programmes
  - Progress monitoring for investors and donors
  - Support for recruitment or selection of senior technical staff
- **www.turquoiseassociates.com/TEC**
- **A Turquoise Associates company**

Content

- The context for product innovation
  - Engine & transmission trends and technologies
  - Electrification of the vehicle
  - Powertrain components
  - Fuels
  - Intelligent use of vehicles
- An orderly progression?
- Conclusions

The context for product innovation

- **EU emissions of CO_2 :**
  - Transport accounts for 25%
  - Road transport produces 85% of the transport total
  - Of this, cars represent 60%, trucks 30% and buses 10%
- **EU Targets are to:**
  - Reduce emissions from cars and vans by 40% and from trucks by 10% by 2020
  - Achieve 5.75% penetration of bio-fuels and 2% penetration of CNG by 2010
  - “Introduce” hydrogen and fuel cells by 2020
  - Achieve planned reduction of regulated emissions and reduce noise

Engine & transmission trends and technologies

- **Downsized but driveable:**
  - Turbocharger/supercharger (including electric) *approx -6% CO_2 each*
  - Electric traction boost (hybridisation)
- **Combustion management:**
  - Variable valve activation → cam-less engine
  - Homogenous charge compression ignition (HCCI) → throttle-less engine
  - Lean NO_x trap (LNT) and Diesel particulate filter (DPF)
- **Efficient and controllable transmissions:**
  - Multi-speed manual / dual clutch automated manual
  - CVT / IVT
  - Fully electric drive

Electrification of the vehicle

- **Displaces mechanical and hydraulic systems**
- **Delivers lower losses, flexible packaging, precise & system level control**
- **Enables X-by-wire (steering, braking, climate control):**
  - Requires reliable fault-tolerant software and hardware
  - Requires algorithms for conflict resolution
- **Enables electric drive-line (requires compact, very efficient traction motors & temperature control)**
- **Promotes electro-mechanical valve actuation**
- **Requires elegant power-net, decisions re. voltages etc, DC-DC converters**
- **Requires bigger and better batteries, with management systems**

Powertrain components

- **Stop-start:**
  - 12V Belt-driven initially, integrated later? *-5% CO_2*
  - Algorithms for hotel load management – e.g. climate extremes
  - Enables regenerative braking *-8% CO_2 with regen brakes?*
- **Exhaust heat recovery:**
  - Thermo-electric or Thermo-fluid
  - Turbo-electric *-6% CO_2 (simulation)*
- **Fuel Cell APU:**
  - Requires hydrogen storage
  - Solid Oxide or PEM or what?
  - Balance of plant

Fuels

- **Impact on engine and powertrain:**
  - Cost of achieving forthcoming air quality standards favours petrol over diesel
  - Dual-fuel and flex-fuel vehicles?
- **Concerns about bio-fuel composition and powertrain durability:**
  - Requires standardisation of bio-fuels
  - Requires lubricants/additives for low losses and low flammability
- **Reliable and robust metrics for sustainability are essential**
  - False starts unwelcome

Intelligent use of vehicles

- **In the control of the driver:**
  - Smooth and gentle with anticipation vs spontaneous and opportunist
- **In the control of the traffic management system:**
  - Green wave / incident diversions, to minimise congestion
- **Enabled by car-to-car and car-to-infrastructure communication:**
  - Transmission mode switching in anticipation of geography / air quality zones
  - Fast response revisions to optimum route

    → *“energy-efficient co-pilot”*

- Don’t mention autonomous vehicles!

An orderly progression?

- **Automotive industry is heavily regulated:**
  - Warranty costs can cripple so radical steps are unusual
  - Vehicle development programmes “freeze” technology 18 months before Job 1
- **Technologies are being introduced in step-wise sequence** (*see UK DfT report by Ricardo Consulting Engineers Ltd*[1]**):**
  - Stop-start technology + regenerative braking (2007) *-23% CO_2 +6% cost*
  - Mild hybrid + significant downsizing (2010) *-34% CO_2 +13% cost*
  - Parallel hybrid + advanced diesel (2012) + heat recovery (2017) + H2 APU (2023) *-50% CO_2 +25% cost*
- **Natural subsequent step - replacement of ICE by fuel cell**

[1] *www.dft.gov.uk/pgr/roads/environment/research/cqvcf/carbontohydrogenroadmapsforp3822*

Conclusions

- **Automotive industry recognises the need for sustained innovation to meet the challenge of CO_2 reductions framed by policy makers**
- **A robust, step-wise path to low carbon cars exists today:**
  - Doesn't require radical step changes
  - Does require a large number of new products to 2020
- **Ultimately, the path leads towards H_2 and fuel cells for traction, if that remains attractive**
- **Several key themes emerge:**
  - Downsizing the ICE
  - Electrification of the vehicle
  - Intelligent use of the car