Meeting the Engine Technology Challenge

Phil Lake

Chief Engineer
Powertrain Development & Attributes
Ford of Europe

January 29th 2008
IMechE, London
Sustainability Roadmap: Powertrain Technologies/Energy Supply

- Engine & Transmission Improvement
- Hybrid Electric Vehicles
- Plug-in HEV's
- Hydrogen Fuel Cell Vehicles
- Reformulated/Bio mass derived fuels
- Petroleum based fuels
- Electricity
- Hydrogen
How we address the Automotive Contribution

Focus is on technologies which have a broad application, are cost effective.
Fuel Economy Stepwise Improvements Examples - Warm Up

• Heat Energy Recovery is a clearly identified opportunity
• To maximise the benefit needs a good systems and physics based approach
Fuel Economy Stepwise Improvements
Examples – Variable Flow Oil Pump

• Variable Flow Oil Pump can significantly reduce the pumping effort on the engine at higher engine speeds resulting in 1 – 2% FE at < £20 / vehicle
Fuel Economy Stepwise Improvements
Examples – Laser Honing

BP/Ford Alliance – Joint Engineering & Development
Powertrain Development: Diesel and Petrol Engines

**Diesel Emissions**
- Direct Injection
- Common Rail FIE
- PM Trap
- "Right Sizing"
- Adv. Boosting
- Low Temperature Combustion (HCCI)
- NOx Catalysis
- Tailored Fuels

**Any Powertrain**
- Power/Torque Increase
- Parasitic Loss Red.
- Weight Red.
- Adv. Controls
- New IC Engine Process
- Direct Fuel Injection
- Boosted HCCI/CAI
- Tailored Fuel
- Integrated Ox. Cat/ PM/NOx Aftertreatm.

**Gasoline Fuel Economy**
- Variable Valve Timing
- Direct Injection
- Stratified Lean Burn
- Common Rail FIE
- Downsizing/Cyl. Deact.
- Adv. Boosting
- Variable Comp. Ratio
- Low Temp. Comb. (CAI)
- NOx Catalysis
Spray Guided DI Turbo Engine
Engine Torque Comparison

- The 2.0 Diesel Engine provides higher nominal engine torque
- The SGDI T/C Engine delivers high torque over a wider revolution range
- Engine torque has to be transformed for the vehicle through the transmission according to available revolution range
Torque at Wheel, Top Gear

- In top gear also the torque at the wheel are at similar levels for Diesel and Gas
- Resulting In-Gear accelerations (i.e. 80-120kph) are equivalent
SGDI X-Brand System Solution

Common Combustion System and Fuel System Components

Sigma 1.6 SGDI

Volvo SI6 SGDI

Jaguar AJV8 SGDI
Fuel Economy Technology Leaps
Engine Downsizing

1.0L I3 Concept
Transmission Development: Manual and Automatic

- **Layshaft**
  - Dual Wet Clutch Transmissions (Wet Powershift) for higher torque applications.
  - Dual Dry Clutch Transmissions (Dry Powershift) for lower and medium torque applications.

- **Any Transmission**
  - Friction reduction
  - Low friction transmission fluids
  - Active transmission fluid warm
  - Dynamic seamless reconnect
  - Weight Red.

- **Epicyclic**
  - Low loss Torque converters
  - 8 speed
  - Clutch lift strategy

- **Future Transmissions**

Feel the difference - Ford
Advanced Transmissions

Getrag – Ford “Powershift”

Fuel Economy Improvement
Gasoline Applications (Base: 6-speed Manual)

Worse  Better
Fuel Economy Improvement [%]

-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Industry Average 3.87
6-speed Manual -5.66
6-speed AT 0.27
VW DSG 11.6
11.19
10.23
6.67

Feel the difference
Plug-In Hybrid Electric Vehicles

Strategic Drivers for PHEV

• **Energy Security** - reduce petroleum imports through the use of electrical energy

• **CO$_2$ / Climate Change** – shift CO$_2$ production to electrical utility industry; increased potential for significant reduction through renewable energy sources (wind, hydro) or nuclear

• **Customer Benefit** – incremental cost of battery must be offset by savings from fuel economy combined with other subsidies from industry/government

• **Competition** – Ford and Toyota are the only OEM’s with full HEVs for sale to the customer
Fuel Cell History at Ford

1999 P2000 HFC CGH2

2000 Ford Focus FC5 Methanol

2000 Ford Focus FCV CGH2

2001 Mazda Premacy Methanol

2005 FCEV Hybrid CGH2

3rd Generation
Fuel Cell On-going Challenges

Significant Technical Breakthroughs are required to make FCVs commercially viable:

- Affordability
- Hydrogen On-Board Storage
- Durability Improvements
- Safety Codes and Standards
- Simultaneous Hydrogen Infrastructure
An integrated approach is required to meet ‘near Zero’ CO₂,

- **Renewable / Bio blended Gasoline & Diesel**
- **Hydrogen from Renewable sources**
Deployment Strategy – CO₂ Improvements Impact All

- Fuel Economy, CO₂ & Tailpipe Emissions
  
  Environmentally responsible vehicles…

- High relative volumes to make a global difference

- Accessibility (Vehicle Purchase & Running Costs)
  
  …Employing affordable technologies & fuels …

- Performance & Driving Practicality
  
  …Which continue to satisfy & delight the user
Conclusions

• No ‘Silver Bullet’ exists – parallel powertrain technology development will continue

• Combined ‘Car & Energy’ solutions will be necessary to achieve fundamental CO$_2$ emission reduction

• Liquid fuels, supplemented with renewables will provide the most practical solutions in the short and medium term

• Technology solutions must be ‘affordable’ to permit wide scale deployment & Global CO$_2$ benefit
  • Vehicle cost
  • Cost of ownership
  • Fuel Infrastructure

• Auto companies, Fuel Companies, Technology suppliers and Governments need to collaborate to facilitate the revolution, and take an holistic approach.
Life-Cycle Approach („Well-To-Wheel“)

- **Research & Product Development**
  - PG1, Innovation, supplier cooperation initiative which supports the individual life cycle stages

- **End-of-Life / Recovery**
  - Use resources in an environmentally efficient way, Reduce environmental burden

- **Production**
  - Env. Management (ISO 14001/EMAS), M3I

- **Vehicle use**
  - Cost of ownership, Agility-tested label, Ford’s Eco Driving, Safety, Ford environmental customer information, etc.

- **Product Sustainability Management Life Cycle Studies**

Feel the difference
"Well-To-Wheel" Overview

CO₂ Emissions

- Petrol
- Diesel
- Gasoline Hybrid
- Bio-ethanol (sugar-beet)
- Bio-ethanol (cellulose)
- Hydrogen Fuel Cell

CO₂ g/km

Absorbed by plants

Feel the difference
## Figure 3.3: Well-To-Wheel (Well-To-Tank + Tank-To-Wheel) greenhouse gas emissions for various fuel and propulsion system combinations

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Well-To-Tank Emissions</th>
<th>Tank-To-Wheel Emissions</th>
<th>Propulsion System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td>2016 ICE</td>
</tr>
<tr>
<td>Natural Gasoline</td>
<td></td>
<td></td>
<td>DI ICE</td>
</tr>
<tr>
<td>Ethanol (50%)</td>
<td></td>
<td></td>
<td>Advanced ICE (g)</td>
</tr>
<tr>
<td>Ethanol (75%)</td>
<td></td>
<td></td>
<td>ICE (g)</td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td>DI ICE</td>
</tr>
<tr>
<td>E85 Ethanol</td>
<td></td>
<td></td>
<td>Advanced DI ICE (g)</td>
</tr>
<tr>
<td>FT-Diesel (Residue-NG)</td>
<td></td>
<td></td>
<td>DI ICE</td>
</tr>
<tr>
<td>FT-Diesel (Residual Wood)</td>
<td></td>
<td></td>
<td>DI ICE</td>
</tr>
<tr>
<td>CNG (EUN-NG-Mix)</td>
<td></td>
<td></td>
<td>ICE</td>
</tr>
<tr>
<td>LH2 (EUN-NG-Mix)</td>
<td></td>
<td></td>
<td>ICE</td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td>DI HEV</td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td>DI HEV</td>
</tr>
<tr>
<td>FT-Diesel (Residual Wood)</td>
<td></td>
<td></td>
<td>HEV</td>
</tr>
<tr>
<td>CGH2 (EUN-NG-Mix on gas)</td>
<td></td>
<td></td>
<td>ICE HEV</td>
</tr>
<tr>
<td>Methanol (Remote-NG)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>CGH2 (Residual Wood)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>CGH2 (EUN-NG-Mix on gas)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>CGH2 (EUN-NG-Mix on gas + CO2)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>CGH2 (EUN-NG-Mix on gas)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>CGH2 (EUN-NG-Mix on gas + CO2)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>LH2 (EUN-NG-Mix)</td>
<td></td>
<td></td>
<td>FC</td>
</tr>
</tbody>
</table>

*Estimated by cycle; **Estimated by EGU-NG calculations; ***Net output from electrolysis on carbon-free basis; **Estimated by NG cycle calculations.*

---

**Feel the difference**

![Ford Logo](https://www.ford.com)