Powertrains for Sustainable Transport Systems: Current Status and Perspectives of Fuel Cells & Hydrogen Technologies

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Chair of the FCH2JU Scientific Committee

http://www.fch.europa.eu/
• Current challenges for the Automotive Industry;
• Powertrains based on FCH2 solutions;
• Brief presentation of FCH2JU;
• Main Achievements;
• Perspectives, MAWPs, AWPs;
• Conclusions.
A Complicated World

- Population: +50% by 2050
- Food: +70% by 2050
- Energy: +100% by 2050
- Climat: +2°C by 2050
Remarkable Achievements

Grams of CO₂ per kilometre for passenger cars:

- 186* g/km (1995)
- 161 g/km (2005)
- 95 g/km (2021)

-42% decrease
-51% decrease

Passenger Cars:

Trucks:

- Petrol NOx
- Diesel NOx
- Diesel PM
### Automotive Electrical Loads

<table>
<thead>
<tr>
<th>Load</th>
<th>Max Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical AC compressor</td>
<td>3.8 to 4.0</td>
</tr>
<tr>
<td>Electrically actuated valve train</td>
<td>3.0 to 3.2</td>
</tr>
<tr>
<td>Preheated catalyst</td>
<td>3.0</td>
</tr>
<tr>
<td>Windshield heating</td>
<td>2.5</td>
</tr>
<tr>
<td>Brake-by-wire</td>
<td>2.0</td>
</tr>
<tr>
<td>Steer-by-wire</td>
<td>1.8</td>
</tr>
<tr>
<td>Mobile AC power outlet</td>
<td>1.5</td>
</tr>
<tr>
<td>Electric power steering</td>
<td>1.0</td>
</tr>
<tr>
<td>Electrohydraulic brakes</td>
<td>0.9</td>
</tr>
<tr>
<td>Lights</td>
<td>0.6</td>
</tr>
<tr>
<td>ABS pump</td>
<td>0.6</td>
</tr>
<tr>
<td>Power windows (front)</td>
<td>0.5 to 0.7</td>
</tr>
<tr>
<td>Power windows (rear)</td>
<td>0.5 to 0.7</td>
</tr>
<tr>
<td>Heated front seats (left and right)</td>
<td>0.5</td>
</tr>
<tr>
<td>Heated rear seats (left and right)</td>
<td>0.5</td>
</tr>
<tr>
<td>High-power stereo</td>
<td>0.3</td>
</tr>
<tr>
<td>Front wiper motor</td>
<td>0.2 to 0.3</td>
</tr>
<tr>
<td>Sunroof motor</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Intelligent Vehicles & Infrastructures

**Intelligent Infrastructure**
- Arterial management
- Freeway management
- Crash prevention & safety
- Road weather management
- Roadway ops & maintenance
- Transit management
- Traffic incident management
- Emergency management
- Electronic payment & pricing
- Traveller information
- Information management
- Commercial vehicle operations
- Inter modal freight
- Traffic management center

**Intelligent Vehicles**
- Collision avoidance
- Driver assistance
- Collision notification
Fuel Options
A Life Cycle Approach

Well-to-Wheels Greenhouse Gas Emissions\(^5\)
(direct emissions, based on a projected state of the technologies in 2020)

- **Gasoline**: 410 grams of CO\(_2\) equivalent per mile
- **Natural Gas**: 320 grams of CO\(_2\) equivalent per mile
- **Diesel**: 250 grams of CO\(_2\) equivalent per mile
- **Corn Ethanol - E85**: 220 grams of CO\(_2\) equivalent per mile
- **Cellulosic Ethanol - E85**: <65 grams of CO\(_2\) equivalent per mile
- **Gasoline**: 190 grams of CO\(_2\) equivalent per mile
- **Cellulosic Ethanol - E85**: <150 grams of CO\(_2\) equivalent per mile
- **H\(_2\) from Distributed Natural Gas**: 200 grams of CO\(_2\) equivalent per mile
- **H\(_2\) from Coal w/Sequestration**: <110 grams of CO\(_2\) equivalent per mile
- **H\(_2\) from Biomass Gasification**: <55 grams of CO\(_2\) equivalent per mile
- **H\(_2\) from Nuclear High-Temp Electrolysis**: 50 grams of CO\(_2\) equivalent per mile
- **H\(_2\) from Central Wind Electrolysis**: <40 grams of CO\(_2\) equivalent per mile

**Conventional Vehicles**

- **Hybrid Electric Vehicles**
- **Plug-in Hybrid Electric Vehicles** (40-mile all-electric range)
- **Fuel Cell Vehicles**

*Today's Gasoline Vehicle*
Hydrogen

H₂ production cost
EUR / kg H₂

CO₂ emissions
kg CO₂ / kg H₂

D/CWE: Decentralized/Centralized Water Electrolysis
D/CSME: Decentralized/Centralized Steam Methane Reforming
CG: Coal Gasification
CCS: Carbon Capture & Storage
IGCC: Integrated Gasification Combined Cycle
Alternative Powertrains

Source: GM Powertrain Strategy - Electrification of the Vehicle
From Dream to Reality
## The State of Art

### Mercedes-Benz B Class
- **Fuel Cell Stack type**: PEM, 80 kW
- **Electric Motor**: 70 kW nominal / 100 kW peak
- **Maximum Torque**: 320 Nm
- **Fuel**: H₂ (70 MPa)
- **Autonomy**: 400 km
- **Maximum Seed**: 170 km/h
- **Battery**: Li-ion

### Daimler Citaro Bus
- **Fuel Cell Stack**: PEM, 120 kW (cont.)
- **Electric Motor**: 2 x 80 kW
- **Fuel**: H₂ 35 kg (35 MPa)
- **Autonomy**: 250 km
- **Battery**: 250 kW
- **Average consumption**: 10-14 kg/100 km
European Climate and Energy Policy Framework

Sustainable development

Our future ?

Security of supply

Competitiveness

From:
The 20-20-20 goals by 2020:
20% increase in renewables
20% increase in efficiency
20% decrease in GHG emissions

To:
The EU targets by 2030*:
• 27% renewable energy
• 27% improvement of energy efficiency
• 40% reduction in GHG emissions

*European Council conclusions of 23/10/2014

Joint Undertaking – Public Private Partnership
Council Regulations:
521/2008 of 30 May 2008 (FP7)
1183/2011 of 14 November 2011
559/2014 of 6 May 2014 (H2020)
Fuel Cells & Hydrogen 2 Joint Undertaking

Industry Grouping
NEW-IG
87 members

European Union
represented by the
European Commission

Research Grouping
N.ERGHY
63 members

To bring to the point of market readiness a portfolio of clean, efficient and competitive solutions based on fuel cells and hydrogen technologies in energy and transport.

The Joint Undertaking is managed by a Governing Board composed of representatives of all three partners and lead by the Industry.
Goals & Means

**TRANSPORT**
- Road vehicles
- Mobile systems and MHS
- Fuel Supply Infrastructure
- Applications in the field of maritime, rail and air

**ENERGY**
- Fuel Cells for CHP
- Distributed production of Hydrogen
- Hydrogen for RES (including injection in NG pipelines)

**CROSSCUTTING ISSUES**
(strandardization, public awarness, manufacturing technologies, studies)

Budget of 1.33 Bln. Euro for the period 2014 – 2020

With a robust involvement of the Industry in the implementation of the programme and by additional investment that could support common goals.
The Big Picture

- **Transport**
  - Reduction of production costs of long lifetime FC systems to be used in transport applications

- **Industrial applications**
  - Increase of the electrical efficiency and durability of low cost FCs used for power production

- **Residential CHP**
  - Increase the energy efficiency of low cost production of hydrogen from water electrolysis and renewable sources

- **Feed to electricity grid**
  - Methanisation feed to natural gas grid

- **Existing natural gas, electricity and transport infrastructures**
  - Reduce the use of critical raw materials

- **By-product from Chemical Industry**
  - Large scale use hydrogen to support integration of renewable energy sources into the energy systems

- **Natural gas, biogas, coal, biomass**
  - Renewable generation, storage and ‘buffering’
Steps Forward

**Call requirements**

- Pt loadings
- Temp. <0°C
- Power density
- Costs
- Power loss

**2020 goals**

- 100 €/kW at 50,000 units per year
- > 6,000 h lifetime

**MEA/FCs status**

From 2009  |  To 2020
--- | ---
Costs | ✔
Durability | ✔
Performance | ✔

With each year call, stringent requirements to meet the 2020 goals.
Achievements

**Car fuel consumption (kgH2/100km)**

Baseline 2008: 1.1
2014: 0.97 (13% reduction)

**Car range (km)**

Baseline 2008: 200
2014: 600 (100% increase)
Achievements

**Bus FC system cost (EUR/kW)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline 2010</th>
<th>2014</th>
<th>2020 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (EUR/kW)</td>
<td>3200</td>
<td>2300</td>
<td>1500</td>
</tr>
<tr>
<td>Change</td>
<td>-29%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Bus FC system lifetime (h)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Baseline 2010</th>
<th>2014</th>
<th>2020 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime (h)</td>
<td>2000</td>
<td>12000</td>
<td>60000</td>
</tr>
<tr>
<td>Change</td>
<td>+350%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Achievements

**Bus fuel consumption (kgH2/100km)**

- Baseline 2010: 20 kgH2/100km
- 2014: 9 kgH2/100km (55% decrease)
- 2020 Target: 5 kgH2/100km

**Bus vehicle cost (kEUR)**

- Baseline 2010: 2500 kEUR
- 2014: 1400 kEUR (40% decrease)
- 2020 Target: 800 kEUR
Likely implementation of the network by 2020 onward (>80 kg/day stations)

- **France**: The French network will keep on expanding with 30-40 HRS by 2020 and 100 HRS by 2023.

- **Germany**: The German network will keep on expanding with 400 HRS in 2023.

- **Netherlands**: The Dutch network will keep on expanding with 20 HRS by 2020 and 40-50 HRS by 2023.

- **Scandinavia**: The Scandinavian network will keep on expanding with 35-40 HRS by 2020 and 50 HRS by 2023.

- **UK**: The UK network will keep on expanding with 60-70 HRS by 2020 and 100 HRS by 2023.
VISION –
FC electric buses commercially viable and rolled-out in Europe

2020 onwards
Conclusions

• Coordinated approach has to be followed for infrastructure build-up with regards to locations, technology, capacity/performance.

• Much more focus and professional approach for putting a strong emphasis on customer views.

• Creative solutions for market deployment have to be encouraged for new approaches as the concept of Infrastructure as a Service.
Thank you for your attention!

Peter Cooper's Tom Thumb Races a Horse

(U.S. Dept. of Transportation, August 28, 1830)