Hydrogen, Fuel Cell and Battery Electric Drives – Federal Market Preparation Programs in Germany, Status Quo & Outlook

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NOW GmbH National Organization Hydrogen and Fuel Cell Technology
Fuel Cell Vehicles and Hydrogen from Renewable Energy Sources are Key Elements of an Integrated Sustainable Energy System

Fuel Cell Vehicles using hydrogen from renewable energy sources are needed to decarbonize the transportation sector

hydrogen produced from renewable power sources is needed to stabilize the power grid

- Hydrogen for industrial processes
- Decentralized power-heat cogeneration
- Energy storage for supply from renewables

- Reforming of natural gas/biogas or gasification of biomass/coal
- Byproduct of the chemical industry
- Water electrolysis

Fuel Cell Vehicles using hydrogen from renewable energy sources are needed to decarbonize the transportation sector.

<table>
<thead>
<tr>
<th>CO₂ emissions well-to-wheel, g CO₂/km</th>
<th>Range, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery electric vehicle</td>
<td>0-200</td>
</tr>
<tr>
<td>Fuel cell electric vehicle</td>
<td>200-600</td>
</tr>
<tr>
<td>Internal combustion engine – gasoline</td>
<td>600-800</td>
</tr>
<tr>
<td>Internal combustion engine – diesel</td>
<td>800-1,200</td>
</tr>
</tbody>
</table>

Low emissions and high range

CO₂ emissions well-to-wheel, g CO₂/km

Hydrogen for industrial processes

Decentralized power-heat cogeneration

Energy storage for supply from renewables

Reforming of natural gas/biogas or gasification of biomass/coal

Byproduct of the chemical industry

Water electrolysis
Market Preparation for Electro-Mobility

Three pillars of electrifying the powertrain

- Battery technology
- Electric Powertrain Technologies
- Hydrogen and fuel cell technologies

**Electric Powertrain Technologies**

- Hybrid vehicles (rail/road)
- Plug-in vehicles and pure battery electric vehicles
- Hydrogen and fuel cells

**Battery Technology**

- 500 mio. € budget (2009-2014);
  - Incl. 150 mio. € BMVBS (2009-2011)
  - ~ 100 mio. € (2011-2014)

**Hydrogen and Fuel Cell Technologies**

- 1.4 bn. € budget (2007-2016);
  - Incl. 700 mio. € federal funding:
    - BMVBS (500 mio. €) and
    - BMWi (200 mio. €)

**Key Technologies for Sustainable Mobility**

- Batteries
- Hydrogen / fuel cells
National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP)
BMVBS-funding Status 01/2013

Total Budget: 1.4 billion € 2007-2016

<table>
<thead>
<tr>
<th>Program Area</th>
<th>Lol &amp; Approved £k</th>
<th>In Discussion £k</th>
<th>Total £k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>226,306</td>
<td>46,075</td>
<td>272,380</td>
</tr>
<tr>
<td>H2-production</td>
<td>15,040</td>
<td>8,537</td>
<td>23,577</td>
</tr>
<tr>
<td>Industrial Applications</td>
<td>33,623</td>
<td>16,858</td>
<td>50,480</td>
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<tr>
<td>Residential Cogeneration</td>
<td>58,347</td>
<td>16,074</td>
<td>74,421</td>
</tr>
<tr>
<td>Special Markets</td>
<td>34,116</td>
<td>21,586</td>
<td>55,701</td>
</tr>
<tr>
<td>Cross-Cutting Issues</td>
<td>18,976</td>
<td>11,664</td>
<td>30,640</td>
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<tr>
<td>Product Line</td>
<td>386,407</td>
<td>120,793</td>
<td>507,200</td>
</tr>
</tbody>
</table>

Total number of projects: 206
Approved / LoI: 138 projects (313 applications)

Yearly Funding Distribution

- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016

BMVBS 68%
BMWi 32%
NIP - Integrated Approach for Market Preparation

Technology
- components
- subsystem
- systems + products

Application
- cost
- reliability
- lifetime

Markets
- customer acceptance
- safety
- approval processes

Bosch: Hydrogen Gas Injector HGI

FCCT: Gas Diffusion Layer (GDL)

Linde: Ionic H2-Compressor

Clean power net: Brennstoffzellen in Industrie und Business

Callux (nip): Praxisstest Brennstoffzelle fürs Eigenheim

CEP (nip): Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellenforschung
The Clean Energy Partnership

• A public-private partnership founded in Dec. 2002 as a joint initiative between the government and industry under the lead management of the Federal Ministry of Transport and Traffic.

• The aim is to think, research and act across industries for a zero-emissions future with hydrogen cars and buses.

• The CEP is the biggest demonstration project in Europe in the field of hydrogen technology, and the lighthouse project of the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP) in the transport sector.

• The NIP is coordinated by NOW GmbH (National Organisation for Hydrogen and Fuel Cell Technology).
Clean Energy Partnership – FCV Fleet

Fuel Cell Vehicles from different OEM`s

- 80 Daimler B-series F-CELL
- 20 Opel Hydrogen4
- 8 Volkswagen Touran, Caddy, Tiguan HyMotion, Audi Q5-HFC
- 5 Toyota FCHV
- 2 Honda FCX Clarity
- Hyundai recently joined the CEP
- 7 Fuel Cell Busses (Evobus) in Hamburg

+3225011616
Daimler AG, Ford Motor Company and Nissan Motor Co., Ltd., have signed a unique three-way agreement to accelerate the commercialization of fuel cell electric vehicle (FCEV) technology.

STUTTGART, Germany (Jan. 28, 2013)

The goal of the collaboration is to jointly develop a common fuel cell electric vehicle system while reducing investment costs associated with the engineering of the technology. Each company will invest equally towards the project. The strategy to maximize design commonality, leverage volume and derive efficiencies through economies of scale will help to launch the world’s first affordable, mass-market FCEVs as early as 2017.

Together, Daimler, Ford and Nissan have more than 60 years of cumulative experience developing FCEVs. Their FCEVs have logged more than 10 million km in test drives around the world in customers’ hands and as part of demonstration projects in diverse conditions. The partners plan to develop a common fuel cell stack and fuel cell system that can be used by each company in the launch of highly differentiated, separately branded FCEVs, which produce no CO2 emissions while driving.

The collaboration sends a clear signal to suppliers, policymakers and the industry to encourage further development of hydrogen refueling stations and other infrastructure necessary to allow the vehicles to be mass-marketed.
BMW Group and Toyota Motor Corporation (TMC) are pursuing their successful strategic long-term cooperation in the field of sustainable mobility today by signing binding agreements aimed at long-term collaboration between the two companies for the joint development of a fuel cell system, joint development of architecture and components for a sports vehicle, and joint research and development of lightweight technologies. These agreements follow a memorandum of understanding signed in June 2012.

Furthermore, BMW Group and TMC also today signed a binding agreement to commence collaborative research on lithium-air batteries, a post-lithium-battery solution. This agreement marks the second phase of collaborative research into next-generation lithium-ion battery cells that commenced in March 2012.

Signing of the contract for the cooperation between BMW Group and Toyota Motor Corporation in Nagoya/Japan on 24 January 2013 ...
Why Fuel Cell Buses?

Strategic approach

- Long term strategy for safe energy supply duly focussed on decreasing availability of fossil fuels
- First Mover: Better perception for public transport
- Protection of revenues („Eco-Bonus“)
- Introduction of new technology only doable step by step
- Sufficient time for education and on-the-job training
- Set up of workshops and refuelling infrastructure subsequently to benefit from technical optimization
- Which storage technology allows vehicle use up to 20 hours per day?
- How can productivity losses in line service be avoided?
- High launching costs still more economic than a direct later implementation!
Framework Conditions

### External
- Implementation of EU clean air regulations in national law
- Transition towards renewable energy
- Buses up to 14 years in use: Long term strategy for safe energy supply
- Growing rate of „environmentally orientated customers“ (no captive riders)
- Consideration of socio-economic developments in mobility
- Future availability and cost of fossil fuels

### Internal
- Introduction of new technology can only be done step by step
- Sufficient time for education and on-the-job training
- Make use of technical optimization in workshops and refuelling infrastructure
- Storage technology to allow for up to 20 hours per day
- Avoid productivity losses in line service
- Launching costs high but more economic than a latter direct implementation
The New Fuel Cell Hybrid Bus

**New generation with fuel cell hybrid system**
- Recuperation system saves energy
- Higher efficiency
- More driving comfort due to low noise system and smooth acceleration
- Optimized availability
- Longer life cycle

**Fuel Cell Bus (CUTE)**

<table>
<thead>
<tr>
<th>Technical Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>205 kW for &lt; 15-20 Sec.</td>
</tr>
<tr>
<td>Range</td>
<td>180 - 220 km</td>
</tr>
<tr>
<td>HV-Battery</td>
<td>--</td>
</tr>
<tr>
<td>Hydrogen Consumption</td>
<td>20 – 24 kg / 100 km</td>
</tr>
<tr>
<td>Max. Efficiency</td>
<td>48 %</td>
</tr>
<tr>
<td>Number of passengers</td>
<td>23 + 49 = 72</td>
</tr>
</tbody>
</table>

**Fuel Cell Hybrid Bus**

<table>
<thead>
<tr>
<th>Technical Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>220 kW for &lt; 15-20 Sec.</td>
</tr>
<tr>
<td>Range</td>
<td>&gt; 250 km (planned)</td>
</tr>
<tr>
<td>HV-Battery</td>
<td>Li-Ion, 180 kW permanent</td>
</tr>
<tr>
<td>Hydrogen Consumption</td>
<td>8 kg / 100 km</td>
</tr>
<tr>
<td>Max. Efficiency</td>
<td>58 %</td>
</tr>
<tr>
<td>Number of passengers</td>
<td>25 + 50 = 76</td>
</tr>
</tbody>
</table>
**Current status**
- 4 Hybrid-FC buses in operation, option for another 3 buses
- 2 x 70 kW FC modules, 35 kg hydrogen on board
- 350 kilometres range
- Guarantee 12,000 hours or 5 years (40,000 h necessary)
- Very comfortable, quiet, good drivability
- Appreciable fuel reduction compared with last bus generation from 22 kg/100 km to 8 kg/100 km
- Up to 250 km/day in line service
- In total ~ 68,000 km up to now since August 2011

**Next steps**
- 3 more vehicles in 2013, next generation by 2017
- Masterplan for implementation of technology with manufacturer
- Only low emission buses to be purchased from 2020
- Depot for low emission buses in planning
Future FC Buses?

Achievements

- Good development progress, optimization potentials widely known
- Support for political motivated energy transition
- Synergies regarding energy supply (storability, use of erratic energy from renewable sources) with political change in overall energy policy
- Easier to handle than other innovative powertrains (battery, trolley etc.)
- Spill-Over effects from passenger cars

Challenges

- No clear indication on reduction of costs
- Roadmap to market viability of manufacturer’s (milestones, timeline) not clear
- Price of hydrogen, market strategy of relevant industry
- Storage of big volumes of hydrogen
- Insufficient communication to / awareness at decision-makers and public
Clean Energy Partnership – Hydrogen Refueling Stations (HRS)

Key achievements
- Safety of stations proven
- Refueling standards agreed
- Storage and compressor technology tested
- H₂ supply chain tested
- Bugs of station technology eliminated
Germany to expand nationwide network of hydrogen filling stations from 15 to 50 by 2015

June 20, 2012

• joint Letter of Intent to expand the network of hydrogen filling stations in Germany
  • signed by the German Ministry of Transport, Building and Urban Development (BMVBS) and several industrial companies
  • part of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP)
  • overall investment more than €40 million (US$51 million)
• market-relevant testing of filling-station technology
• ensure a needs-driven supply for fuel cell vehicles
• coordination by NOW GmbH in the frame of the Clean Energy Partnership (CEP)

„To facilitate market introduction [of fuel cell vehicles] we need a hydrogen station network covering and connecting the metropolitan regions.“

Dr. Peter Ramsauer, Federal Minister for Transport, Building and Urban Development
Demonstrating Wind-Hydrogen for Mobility

Hydrogen as part of an integrated energy system → renewable hydrogen as a fuel system

Enertrag: Hybrid Power Plant

Total: Refueling Station at Heidestr., Berlin
First delivery of wind-hydrogen on April 18th, 2012
Major Global Infrastructure Activities

UK H₂ Mobility
- Phase 1 accomplished

H₂-Mobility France
- In preparation

TEN-T

USA (California)
- 68 HRS till 2015
- 5000 FCEVS till 2015

New H₂-USA

Japan
- 1000 HRS till 2025
- 1 Mio. FCEV’s till 2025

South Korea
- 500 HRS till 2020
- 50,000 FCEV’s till 2020

China
- 5 HRS till 2015
- 1.000 FCEV’s till 2015

Scandinavian Hydrogen Highway Partnership
- 45 HRS / 2015
- 500 cars / 2015

H₂ Mobility
- a total of 100 HRS (50 within the CEP) / 2015
- 5000 cars / 2015

H₂ SWISS MOBILITY
- 10-15 HRS
Goals and Implementation of the Model Regions

A program funded by BMVBS
Part of the stimulus package of the German government (2009-2011) and beyond

Goals
• Experience from day-to-day operation as a basis for commercialization

Implementation
• Integrated mobility concepts focused in regional clusters (local networks)
• National-wide exchange of experiences in topic-specific platforms
BMVBS Eight Model Regions (2009-2014)
Almost 2,200 battery-electric vehicles in day-to-day operation

- Zweiräder
- PKW
- Pedelecs
- Busse
- Nutzfahrzeuge

Hamburg
108 vehicles*
* additional 215 vehicles since Oct. 2011

Bremen / Oldenburg
101 vehicles

Rhein – Ruhr
196 vehicles

Rhein – Main
552 vehicles

Stuttgart
775 vehicles

Berlin / Potsdam
218 vehicles

Sachsen
66 vehicles

München
69 vehicles
Model Regions (2011-2016)
Knowledge transfer through accompanying research

Joint Strategy Meetings

Topics of accompanying research:
- User perspective
- Business and application models
- Innovative drives and vehicles
- Security
- Infrastructure
- Urban and transport planning
- Regulative law

Programm Scope
- About 20 new projects started in 2011
- About 40 projects to start in 2012
- At least 200 partners (incl. associated partners) from research, utilities, municipalities and with automotive background

Central Datenmonitoring

Model regions (projects):
THANK YOU!