Market Preparation for Hydrogen and Fuel Cell Technologies

The German Model

Dr. Klaus Bonhoff
NOW GmbH | Managing Director (Chair)

Making Way for Scotland’s Hydrogen Economy
Edinburgh Council Chambers, Edinburgh, Scotland
September 29, 2010
Preparing Hydrogen and Fuel Cell Markets: National Innovation Programme (NIP)

1.4 billion €
2007-2016

+ 700 million €
Co-payment from industry

<table>
<thead>
<tr>
<th>Politics</th>
<th>Industry</th>
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<tbody>
<tr>
<td>BMVBS / BMWi / BMBF / BMU</td>
<td></td>
</tr>
<tr>
<td>500 million €</td>
<td>+ 200 million €</td>
</tr>
<tr>
<td>for demonstration</td>
<td>for R&amp;D</td>
</tr>
</tbody>
</table>

- Preparing hydrogen & fuel cell markets
- Focus on R&D combined with everyday demonstration
- Hydrogen & fuel cells driven by applications and markets: transport, stationary energy supply, special markets
Approved Projects
Demonstration (BMVBS) and R&D (BMWi) (status 09/2010)
STATIONARY ENERGY SUPPLY PROGRAMME AREA
Demonstration
Residential Co-Generation
Power Plant in Barth from DALKIA
MCFC operated with Biogas

WHEC 2010, Essen, Germany
"Speicherstadt Potsdam"
Integrated Energy Concept

1. Energy Efficient Building (Modernizing)
2. Efficient supply of power, heat and cold (tri-generation) with fuel cells
3. CO$_2$-neutral Biogas Production
E4ships

Fuel Cells in Maritime Applications

WHEC 2010, Essen, Germany
SPECIAL MARKETS PROGRAMME AREA
Fuel Cells in Critical Power Supply / Back-up Power

Energy

Tunnel

Transportation

Environment

Telecom

IT

Chemistry

Mining
Fuel Cells in Leisure Applications and Tourism Markets

- On-board power supply in caravans, boats etc.
- Special vehicles
- Grid-independent power supply
The governmental E-Mobility activities strive for the electrification of drivetrains based on three major pillars:

- **Electrification of drives (E-Mobility)**
  - Hybrid-vehicles (road & rail)
  - Plug-in-vehicles and fully electric vehicles
  - Hydrogen and fuel cells

The overall E-Mobility activities are divided into the fields of battery technology and hydrogen / fuel cells.
The Model Regions

• A Program on Battery Electric Mobility
• Funded by the Federal Ministry of Transport, Building and Urban Affairs (BMVBS)
8 Pilot Regions: Goal, Background and Focus

- **Goals:** combine applied research and development centering on day-to-day and user-focused demonstration and the intention of the stimulus package to boost the economy.

- **Background:** electric mobility is to be developed adopting a holistic and integrated approach, with a different focus in each region.

- **Cluster:** Motivated regional stakeholders, different requirements are to be taken into account (“subsidiarity”), creativity of regional initiatives is to be exploited.

- **Major elements:** R&D to prepare demonstration, demonstration projects in 8 regions, evaluation.

- Over 200 Partners in more than 70 Projects
Integration of Multiple Mobility Concepts in the Model Regions

- Individual Transport: Cars
- Individual Transport: Bikes etc.
- Commercial Applications: Light Duty vehicles, Heavy Duty Vehicles
- Urban Planning: Initial Charging Infrastructure
- Socio-economic Research
- Public Transport: Hybridbusses and Rail Vehicles
- Demonstration of Vehicles

Modellregionen Elektromobilität

NOW

15
Overview of Planned Vehicles in the Model Regions

<table>
<thead>
<tr>
<th>Modell Region</th>
<th>Busses</th>
<th>cars</th>
<th>LDV/HDV</th>
<th>Scooter/E-Roller</th>
<th>Pedelecs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berlin/Potsdam</td>
<td>10</td>
<td>160</td>
<td>5</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Hamburg</td>
<td></td>
<td>70</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bremen/Oldenburg</td>
<td>20</td>
<td>89</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Sachsen</td>
<td></td>
<td>26</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhein-Ruhr</td>
<td>21</td>
<td>171</td>
<td>21</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Rhein-Main</td>
<td>4</td>
<td>45</td>
<td>4</td>
<td>575</td>
<td>480</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>6</td>
<td>33</td>
<td>50</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>München</td>
<td>1</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vehicles</strong></td>
<td>62</td>
<td>654</td>
<td>137</td>
<td>753</td>
<td>1210</td>
</tr>
</tbody>
</table>
## Overview partners infrastructure

<table>
<thead>
<tr>
<th>Model regions</th>
<th>Actors / partners</th>
<th>Number of charging spots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamburg</td>
<td>Hamburg Energie, Vattenfall Europe, DB AG, Stadt Hamburg (Behörde für Stadtentwicklung und Umwelt sowie Landesbetrieb Straßen, Brücken und Gewässer)</td>
<td>100 public</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150 semi-public</td>
</tr>
<tr>
<td>Nord West (Bremen/Oldenburg)</td>
<td>BREOPARK GmbH, die Städtische Parkgesellschaft Bremerhaven mbH, EWE, Airport Bremen und die Bremer Straßenbahn Aktiengesellschaft</td>
<td>10 public</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 private</td>
</tr>
<tr>
<td>Berlin/Potsdam</td>
<td>RWE, APCOA, Siemens, Vattenfall, ADAC, IHK Berlin, Elektroinnung Berlin, REWE, Contipark, IAV, Total, Messe Berlin und Gravis, Deutschen Bahn AG</td>
<td>600 total</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500 public and semi-public (76 in operation)</td>
</tr>
<tr>
<td>Rhein-Ruhr</td>
<td>RheinEnergie, Stadtwerke Düsseldorf, Stadtwerke Aachen-STAWAG und RWE Effizienz GmbH</td>
<td>500 public, semi-public and private</td>
</tr>
<tr>
<td>Rhein-Main</td>
<td>u.a. Stadtwerke Offenbach, Mainova AG, UPS, Offenbacher Verkehrsbetriebe, Rhein-Main Verkehrssverbund, Energieversorgung Offenbach, Städtische Werke AG</td>
<td>115 public, semi-public and private</td>
</tr>
<tr>
<td>Sachsen</td>
<td>ENSO Netz GmbH, DREWAG Stadtwerke Dresden GmbH, und die Stadtwerke Leipzig, KEMA-IEV Ingenieurunternehmen für Energieversorgung GmbH und die Hochschule für Telekommunikation Leipzig</td>
<td>8 public, 25 semi-public, 32 privaté (65 total)</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>EnBW AG (Rollout &amp; Betrieb der Ladesäulen in Stuttgart), die Robert Bosch GmbH (Entwicklung der Ladestationen für den öffentl. sowie gewerblichen/privaten Raum), das EIFER Institut (Analyse Ladestationsorte in Stuttgart), die Stadtwerke Ludwigshburg, die Landeshauptstadt Stuttgart, DB Logistics und sonstige Eigentümer der Standorte wie Handwerkskammer, Landkreise und weitere</td>
<td>630 (80 public, 500 semi-public, 50 private)</td>
</tr>
<tr>
<td>München</td>
<td>AUDI AG, BMW AG, SIEMENS AG, E.ON Energie AG, Stadtwerke München GmbH, Forschungsstelle für Energiewirtschaft mbH, Technische Universität München, fortiss GmbH, Münchner Verkehrsgesellschaft mbH</td>
<td>260 (16 in operation)</td>
</tr>
</tbody>
</table>
Platforms to connect regional activities

1. Communications and expectations management
2. Legal framework
3. Social science and acceptance
4. Environment and Safety
5. Buses
6. Passenger cars and LT
7. Infrastructure
TRANSPORT AND INFRASTRUCTURE PROGRAMME AREA
A strong partnership for a zero-emissions future

This includes:

- the continuous operation of efficient hydrogen vehicles
- their fast and safe refuelling,
- the clean and sustainable production of hydrogen,
- hydrogen transport and storage in liquid and gaseous states
- the increasing integration of renewable energy sources

A lighthouse project within the National Hydrogen Fuel Cell Technology Innovation Program (NIP)
Assembling a new infrastructure ...

BERLIN
• Spandau
• Holzmarktstrasse
• Southern Berlin
• Heidestrasse
• Additional sites are in planning
Opening of the Hydrogen Fuelling Station at Holzmarktstr., Berlin and Rallye from Berlin to Hamburg on May 12, 2010
Opening in 2011

Fuels:
- conventional, CNG (from biogas), LPG, electricity
- Gaseous hydrogen at 350 and 700 bar
- On-site production: electrolysis using wind power from ENERTRAG
- First CO2-free gas station in Germany

Planned Station
Berlin Schönefeld Airport
Building the Hydrogen Infrastructure

Hamburg Hafencity
Ensuring clean mobility …

Daimler B-Class F-Cell

- No. of vehicles: up to 60
- Technology: fuel cell
- Fuel: gaseous hydrogen, 700 bar
- Engine power: 100 kW
- Peak speed: 170 km/h
- Reach: approx. 400 km
GM Opel HydroGen4

- No. of vehicles: 10
- Technology: fuel cell
- Fuel: gaseous hydrogen, 700 bar
- Engine power: 73 kW
- Peak speed: 160 km/h
- Reach: approx. 320 km

… and even more cars to choose from
Supply Industry
Key Components for Next Generation Vehicles

- Power Electronics
- Fuel Cell Stack
- Fuel Cell System
- Hydrogen ICE
- Hydrogen Storage
- Kathode Air Supply
- Hydrogen Supply
System cost reductions of more than 90% were achieved through integration of components, optimized manufacturing processes, use of new materials and technologies and economies of scale.

Source: NuCellSys; Project “System Test of Next Generation Fuel Cell (DV HyWay4)”
Reliability of fuel cell components has tripled in recent years. The next generation is expected to demonstrate double the current reliability.

Hydrogen Production
A Portfolio of Options

- Chemical By-product
- Biomass
- Wind
- Coal
- Natural Gas

Image: Linde AG
Impact of Hydrogen on CO2 Fleet Emissions

Fleet Emissions in Germany (passenger cars)

without fuel production (tank-to-wheel)
g CO₂/km

with fuel production (well-to-wheel)
g CO₂/km

Moderate
Resources
Climate
Hydrogen Production
Focussing on Wind Power and Biomass

Increased Wind Capacity will make wind power the most important source for hydrogen production beyond 2020.

Large scale Electrolyser is a key technology.

Studies show potential for wind-hydrogen-systems to store large quantities of fluctuating energy.

Biomass will play an important role as feedstock for hydrogen production beyond 2020.

Gasification technologies are key.
Project: Renewable Hydrogen

Demonstration of Wind-H$_2$ System
- Concept, Construction, Operation
- Covering power requirements of WTG
- Integration with regional energy infrastructure
- Runtime 2009 to 2013
Integrated System Approach
Combining Different Energy Technologies

• „Based on current knowledge and subject to a variety of prerequisites and conditions, the signing OEMs strongly anticipate that from 2015 onwards a quite significant number of fuel cell vehicles could be commercialised. This number is aimed at a few hundred thousand (100.000) units over life cycle on a worldwide basis.“

• „[...] The signing OEMs strongly support the idea of building-up a hydrogen infrastructure in Europe, with Germany as starting point and at the same time developing similar concepts for market penetration of hydrogen infrastructure in other regions of the world, with one US market, Japan and Korea as further starting points.“
“H₂-Mobility” Initiative –
Overcoming the Chicken and Egg Dilemma

- Signing of Memorandum of Understanding for “H₂ Mobility” Sept. 10th in Berlin
- Eight key stakeholders from industry (OEM, oil, utility & industrial gas) and NOW as public-private-partnership
- Intention to jointly build up hydrogen fueling infrastructure and establishing Germany as lead market
Organisation of the H₂-Mobility Consortium

Working Groups set up to achieve Phase 1 (facilitated by McKinsey)

- Customer Value Proposition, H₂-Production & Supply, Hydrogen Fuel Station Technology Roadmap, Incentives Schemes, Economic Modelling (including network planning), Future Consortium and three support WGs

<table>
<thead>
<tr>
<th>WG CVP</th>
<th>FCV Price / Car Introduction Scenarios</th>
<th>Clean room</th>
</tr>
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<tbody>
<tr>
<td>WG HFS Technology Roadmap</td>
<td>Station Concept / Module Cost</td>
<td>Clean room</td>
</tr>
<tr>
<td>WG H₂-Production</td>
<td>H₂-Cost</td>
<td>Clean room</td>
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Verified and Neutralized Data
Economic Model
# Fuel cell vehicle commercialization plan

## Process

<table>
<thead>
<tr>
<th>Process</th>
<th>Preparation</th>
<th>1. Performance across the hydrogen &amp; electric value chain</th>
<th>2a. H₂ Mobility: Develop German FCV implementation plan</th>
<th>2b. H₂ Mobility: JV set up</th>
<th>3. Formulate EU roll out scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies validate basic data on current and future cost and performance of BEVs, PHEVs, FCVs and ICEs by segment</td>
<td>~6 months</td>
<td>- Companies do the analysis for major parts of the work and jointly build business case&lt;br&gt;- Regular steering committees and workshops&lt;br&gt;- Managed by McKinsey</td>
<td>- Joint process of developing insights &amp; recommendations&lt;br&gt;- Led by consortium, facilitated by external consultant (public tender)</td>
<td>Q2 2011 4 - 6 months</td>
<td></td>
</tr>
<tr>
<td>Regular steering committees and workshops</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managed by McKinsey</td>
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</tbody>
</table>

## Deliverable

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Preparation</th>
<th>1. Performance across the hydrogen &amp; electric value chain</th>
<th>2a. H₂ Mobility: Develop German FCV implementation plan</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Fact based report comparing value chains of BEVs, PHEVs, FCVs and ICEs along value chain</td>
<td>~6 months</td>
<td>- Business plan, incentive schemes, JV set up</td>
<td>- Report with H₂ business case for EU, EU roadmap, and funding requirements</td>
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</table>

## Stakeholders involved and roles

<table>
<thead>
<tr>
<th>Stakeholders involved and roles</th>
<th>Preparation</th>
<th>1. Performance across the hydrogen &amp; electric value chain</th>
<th>2a. H₂ Mobility: Develop German FCV implementation plan</th>
<th>2b. H₂ Mobility: JV set up</th>
<th>3. Formulate EU roll out scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 organisations involved</td>
<td>~6 months</td>
<td>- 9 – 16 parties involved:&lt;br&gt;- Car OEMs, Utility, Oil, Gas, Equipment&lt;br&gt;- German government facilitates group</td>
<td>- 30+ parties involved:&lt;br&gt;- Companies&lt;br&gt;- Selected national governments, EC, JTI&lt;br&gt;- NGOs, and public entities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car OEMs with FCVs, Evs, Hydrogen producers and distributors, Wind, Gas, Power companies, NGOs, and public entities</td>
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<td></td>
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</tr>
</tbody>
</table>

## Funding

- `= private funding`
- `= private + German funding`
- `= private + JTI funding`
NOW GmbH
National Organization Hydrogen and Fuel Cell Technology

- Government-owned company (100 %)
- Co-financing by industry (project overheads)
- Supervisory board: BMVBS (Chair), BMWi, BMBF, BMU
- Advisory board: strategic controlling and development of programmes

NOW
Program Management / International Cooperation / Communication

NIP
Preparing hydrogen and fuel cell markets

BMVBS Electric Mobility
Electric Mobility with Battery-Technologies

Lighthouse projects
Model regions

Germany develops into lead market for sustainable mobility and energy technologies

Dr. Klaus Bonhoff - NOW - Managing Director (Chair)
National Innovation Programme Hydrogen and Fuel Cell Technologies
• Transport and Infrastructure
• Stationary Energy Supply
• Special Markets

Battery-Electric Mobility
• Modellregions

www.now-gmbh.de
Thank you!

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