Matthias Altmann

Towards a

European Hydrogen Roadmap

L-B-Systemtechnik GmbH
Ottobrunn, Germany
www.lbst.de
Presentation overview

1. Drivers towards Hydrogen
   - Superior Technology
   - Energy Security
   - Climate Protection
   - Industrial Competitiveness

2. Hydrogen Roadmap Elements in Europe
   - European Stakeholder Consensus
   - JRC Studies
   - European H₂&FC Technology Platform
   - HyNet - HyWays
Drivers towards Hydrogen

Road Transport Fuel

- GM/Opel
- Toyota
- Honda
- DaimlerChrysler
- Toyota-Hino
- Hyundai
- Ford
- Nissan
- BMW
- DaimlerChrysler
- Munich LH2 station
- Takamatsu H2 station
- California FC Partnership

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Drivers towards Hydrogen

Superior Technology: "Rolling Electric Plug"

Source: DaimlerChrysler
Drivers towards Hydrogen


GM Autonomy

Toyota Fine-N

GM Hy-Wire
Drivers towards Hydrogen

Superior Technology: „Fun to Drive“

[Images of cars]
Drivers towards Hydrogen
Superior Technology: Reduced Development Costs

Fuel cells are modular and scaleable.

Developing power trains with different power ratings or other characteristics from an existing, commercially viable fuel cell power train will require significantly less efforts than developing a new internal combustion engine.
Drivers towards Hydrogen

Energy Security: ExxonMobil: Oil Discoveries ↓ and Oil Prices ↑

Average decline of oil discoveries since 1965: 3.5% per year

Source: The Future of the Oil & Gas Industry: Past Approaches/new challenges, Harry J. Longwell, 7.5.2002
Drivers towards Hydrogen

Energy Security: Hydrogen - Diversification and Infinite Energies

- Renewable Electricity
- Electrolysis and Liquefaction
- Natural Gas Reformer
- Biomass Gasifier
- Transport
- Chemical By-Product
- Hydrogen Storage
- Stationary Applications
- Mobile Applications
- Domestic Energy Supply
- CHP

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Drivers towards Hydrogen

Climate Protection: Floods, Draughts, Storms Cause Economic Damage

Economic and insured economic losses caused by natural catastrophes

Source: Munich Re, TOPICS geo - Annual Review: Natural Catastrophes 2003
Fuel consumption of vehicles and energy requirements and GHG emissions for vehicle manufacturing:
Drivers towards Hydrogen

Industrial Competitiveness: „World Class European H2&FC Technologies“

70 MPa CGH$_2$
Coupling by
Walther
Präzisionsbau

Weh Coupling
for CGH$_2$ at 35 MPa
Global Standard Setting
at SAE J2600
and
ISO 17268

LH$_2$ Coupling by
Linde

GM/Opel, Germany

GM/Opel, Ariake, Japan

BMW, Oxnard, CA, USA

MAN, Berlin, Germany

DC, Madrid, Spain

Ford, Berlin, Germany

GM/Opel, Germany

GM/Opel, USA
Drivers towards Hydrogen

Technical and Economic Challenges

- Fuel cell lifetime
- High power density, low platinum load, sufficient lifetime and mass manufacturability in one stack technology

**Fuel cell operating temperature**
- Fuel cell system complexity

**Hydrogen storage technology**
- Hydrogen storage mass manufacturability

- Fuel cell manufacturing costs
- Hydrogen onboard storage manufacturing costs
„Hydrogen Energy and Fuel Cells - A vision of our future“
Final report of the High Level Group for Hydrogen and Fuel Cell Technologies
June 2003

December 2003

„Well-to-Wheels analysis of future automotive fuels and powertrains in the European context“
EUCAR, CONCAWE, JRC/IES with scientific support by L-B-Systemtechnik GmbH (Well-to-Tank) and Institut Français du Pétrole (Tank-to-Wheel)
Januar 2004
http://ies.jrc.cec.eu.int/Download/eh/31
„Potential of hydrogen as a fuel for transport in the long term (2020 to 2030)“
Carried out by L-B-Systemtechnik on behalf of the Joint Research Centre of the European Commission, Institute for Prospective Technological Studies (JRC/IPTS)
Januar 2004

„Assessing the International Position of EU‘s Research and Technological Development & Demonstration (RTD&D) on Hydrogen and Fuel Cells“
VTT, QinetiQ, Fraunhofer ISI, JRC/IPTS
To be presented at Valencia, Spain, 24 June 2004
Hydrogen Roadmap Elements in Europe

European H₂&FC Technology Platform

H₂/ FC TECHNOLOGY PLATFORM

- Member States' Mirror Group
- Advisory Council (incl. Executive Group)
- TP Secretariat Information Office IT Support Service

**Strategic Research Agenda**

**Deployment Strategy (incl. policy framework)**

**PLATFORM OPERATIONS**

*New and on-going projects and initiatives (EC + MS national, regional and local)*

**GENERAL ASSEMBLY**

*(Bi-)annual Technology Platform Forum*
„Towards a European Hydrogen Energy Roadmap
Preface to HyWays – the European Hydrogen Energy Roadmap
Integrated Project“
Executive Report
12 May 2004
History of HyNet Hydrogen Roadmap

Preparation of HyWays

Agreement between EC and HyNet

Strategic input from HLG

Intermediate meetings

Involvement of hydrogen stakeholders

H2 Review at MATRIX Workshop

Strategic input to AFCG

Intermediate meetings

Harmonisation with Hydrogen Technology Platform

Presentation at HTP Launch Conference

21 February 2003 Brussels

21/22 July 2003 Amsterdam

21 January 2004 Brussels

www.HyNet.info
Profile of HyNet Roadmap Expert Workshop Participants

By region/member state

By sector

- Research Consulting
- Industry

By sector:
- Government
- Associations
- Consulting
- Institutes
- Service
- Equipment
- Auto
- Process
- Utility
- Oil

www.HyNet.info
Integrated Approach by all Stakeholders to Find Answers for

- Tentative quantitative/qualitative build-up scenarios
- Identification of current status and needs&gaps
- Need and structuring of measures

for the topics

- Hydrogen Production and Infrastructure
- Hydrogen Applications and Storage
- Hydrogen Codes&Standards and Regulations
- Socio-Economic and Policy Issues
- Dissemination and Public Outreach
Maturity of Hydrogen Production Technologies

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**Renewable**
- Electrolysis from Renewable Electricity
- Biomass Gasification (w/o or with CO₂ Sequestration)

**CO₂-free**
- Electrolysis from Nuclear Electricity
- Electrolysis from Fossil Fuel derived Electricity with CO₂ Seq
- Reforming of Fossil Fuels (NG, Oil, Coal) with CO₂ Seq

**Fossil**
- Hydrogen from Coal
- Hydrogen from Oil
- Decentralised Small Natural Gas Reforming
- Centralised Natural Gas Reforming

**Photochemical**
- Nuclear (Thermocycles)

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Hydrogen vehicle fuel production EU 2020: 2.3 - 20.6 billion Nm³/a
[Source: HyNet scenarios]
Scenarios for Hydrogen Car Population Development

Today EU-wide
Total cars: ~200 Mio
H₂-production: ~5,4 Mio t\textsubscript{H₂}/a

Assumptions:
H₂-ICE (market entry, high load range): 4.7 l\textsubscript{DE}/100 km
H₂-FC (medium to long term): 2.6 l\textsubscript{DE}/100 km

9 Mio cars
~5% of all cars
~1.5 Mio t\textsubscript{H₂}/a

2 Mio cars
~1% of all cars
~0.3 Mio t\textsubscript{H₂}/a

DE: diesel equivalent
Acceleration of Hydrogen Vehicle Fuelling Station Build-up

Customer view: „Hydrogen served at each corner“

Fuel provider view: „>500 vehicles served per fuelling station“

Accelerating fuelling infrastructure build-up (Private-public incentives!)

Vehicle population

Fuelling station build-up velocity (Lighthouse projects!)

Initialisation
Demonstration
Transition
Full implementation

Minimum coverage plateau
for 2 - 9 million cars:
5,000 - 10,000 fuelling stations
(4 -8% of all ~135,000 EU-fuelling stations)

Total investment:
4 - 15 billion €

Type:
LCGH₂ (central)
CGH₂ (decentral)

Fuelling stations in operation

Type:
LCGH₂ (central)
CGH₂ (decentral)

Total investment:
4 - 15 billion €
Recommendations - Hydrogen Fuel Provision

- At the end of the transition phase (> 1% penetration rate) hydrogen industrial cost from natural gas, at the fuelling station, is expected to be about twice the market price of gasoline/Diesel (w/o taxes and margins)
- In demonstration phase additional by-product hydrogen is available
- In medium to long term, hydrogen has to be produced quasi CO$_2$-neutral, and from renewables to achieve significant CO$_2$ reduction effects from transport
- Integration aspects of hydrogen pathways in lighthouse projects shall be investigated including
  - central and distributed schemes options
  - synergies of transport and stationary end-use
- R&D efforts specifically needed for sustainable hydrogen pathways
Recommendations - Hydrogen for Transport

Stimulate deployment programmes for next generation $\text{H}_2$ vehicles in 2005 – 2010

- Pre-competitive public/private partnerships with x-100 new vehicles p.a.
- Acceleration of vehicle development by public co-funding (e.g. Lighthouse Projects)
- Incorporate in Strategic Hydrogen Research Agenda: research focus on advanced hydrogen storage and powertrain technologies (short to medium term market: ICE, medium to long term market: FCs)

Provide transition to free, competing markets for post 2010 time frame

- Public procurement can create stable environment and limits development risks for applications and infrastructure provider
- Set of EU wide incentives for commercial fleets and early adopters need to be in place around 2012 (fiscal & depreciation incentives, fixed duration & clear exit strategy)
Recommendations - Hydrogen for Stationary/Portable Use

Short term actions with focus on fuel cell technology

- Utilise early but low impact market entry of portable FCs until 2006 to broadly introduce FC and hydrogen image and foster infrastructure synergy with stationary/transport
- As no H$_2$ infrastructure is in place during market entry (2006 - 2008) stationary FCs will use existing fuel infrastructures (Natural Gas, LPG...)
- Large scale demonstration tests on all FC types required all across EU

Stationary hydrogen infrastructure as medium to long term perspective

- To prepare for the medium to long term which will require an increasing amount of H$_2$ for energy storage
  - local H$_2$ infrastructure clusters should be built centering around refuelling stations for public and private road transport
  - H$_2$ should be provided in supply islands, including real islands
- Grid-regulation from off-shore wind (base load wind power) or other renewable energies in the medium to long term
Recommendations - Hydrogen Regulations, Codes & Standards

Confidence in hydrogen to become a safe “public fuel” depends on:

- Existing set of EU-wide regulations/technical standards relevant for hydrogen applications have to be implemented on national level for practical use
- Commitment and participation of authorities, R&D institutions, and commercial companies in the development and implementation of technical solutions, regulations and standards related to hydrogen safety
- Global collaboration in the development of internationally harmonised rules is specifically important for global vehicle and fuel markets
- Validation of safe applications, codes & standards in demonstration projects
- Continuous and systematic governmental and industrial funding for competence building measures to improve level of expertise in authorities and organisations assisting in approval processes
- Communication that industry works on standards which ensure safe products
Conclusions - Dissemination and Public Outreach

Target groups of highest priority:

- regulatory authorities (implementation of codes & standards and regulations)
- national, regional and local governments
- students, educators, people defining national curricula
- media, mechanics and technicians

Required measures aiming at private and expert level:

- information and dissemination activities
- leverage of demonstrations for educational purposes
- fostering of coalitions and partnerships to promote education and outreach
- information gathering and management of demonstrations
- expectation management
- reporting on results and lessons learned in EC research projects
Critical Socio-Economic Issues in Transition Phase

Advocacy / education of policy makers

Education of engineers & staff

Strategic Scenario Analysis (e.g. HyWays)

Initiate public awareness around existing projects

Public awareness campaign with lighthouse projects

Specific entry barriers/ opportunities need to be solved

Solving the financial bridge

Potential labour/ welfare impact (transport driven) starts becoming significant

Revision of Strategy (Market support by target setting & refining)

Materialisation of environmental effects & economies of scale

Renewables

2004

2012

2020

2030

2050

general issues

Issues for transport

Issues for stationary
Critical Policy Issues in Transition Phase

- Ensure Codes & Standards
- Stimulate R & D
- Hydrogen and Fuel Cell Technology Platform
- International Partnership for H₂
- Include H₂/FC Technologies in CHP Directive
- Encourage use of H₂/FC Technologies in Local planning & building regulations

Goal: GTR (global technical regulations) and ISO Standards for H₂ applications

Revision of Strategy (Market support by target setting & refining)

- EU H₂ support measures in place
- EU-Target: 2% H₂ fuel market share
- EU-Target: 5% H₂ fuel market share

- Fleets & Public procurement
- No disadvantage for H₂/FC Technologies in fully liberalised power & gas markets
- Renewables share in EU doubled from 1990 to 2010 (12%)

- WEEE-directive on electrical & electronic equipment
- market entry transport
- market entry stationary
- market entry portables

- General issues
- Issues for transport
- Issues for portable
- Issues for stationary

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Evolution To Member State Validation - HyNet ➔ HyWays

**Qualitative**
- **Vision**
  - Stakeholder consensus on tentative quantitative key objectives

**Detail**
- Evaluation of technical options
  - Develop rules for economic and policy consistency of objectives and 1<sup>st</sup> order EU roadmap (6 countries)

**Quantitative**
- Harmonised, strategic recommendations for action by all stakeholders at all levels (macro, meso, micro) evaluation and final validation of economic consequences (costs, benefits) for all stakeholders

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**Scope**

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<th>National/Regional</th>
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<td>EU</td>
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<td>6 core partner Member states</td>
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<td>Other partner Member states</td>
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</tbody>
</table>

- HyNet
- HLG
- AFCG

- HyWays (Phase I)
- HyWays (Phase II)
- HyWays (Phase II)

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2003
2004
2005
2006
CO₂ in atmosphere limited to maximum 550 ppm
- Limits for non-CO₂ greenhouse gases
- Emission trading and CO₂ taxation
- Targets for renewable energy

Regulations for air quality within cities
Supply security
European competitiveness
HyWays Partnership

**Industry**

Auto: BMW-D, DaimlerChrysler-D, Opel-D  
Oil: bp-UK, Norsk Hydro-N, Repsol-E, Total-F  
Power: EdF-F, Vattenfall-Europe/D, Statkraft-N  
Gas: Air Liquide-F, Air Products-UK, Linde-D, Messer-D, Vandenborre Techn.-B  
Others: GE-I, Hoechst-infraserv-D, Hexion-NL

**Member states**

Phase I: D, F, GR, I, N, NL (existing national hydrogen programs)  
Phase II: all other member states depending on interest

**Working Group Coordinators**

CEA(F), ECN(NL), ENEA(I), FhG-ISI(D), ICCTM(UK), IST(PT), LBST(D), ULP(F), ZEW(D)
HyWays - Work Package Structure

WP0 General Project Management

WP1
- Technology Assessment and Data Collection
- LBST, CEA, ECN, Ind., MS

WP2
- WTW and STU analysis
- CEA, LBST, ECN Ind., MS

WP3
- Socio-economic analysis:
  - H₂ scenarios
  - Energy models
  - Macro-economic analysis (input/output, equilibrium)
  - Emissions analysis
- IST, ECN, ICSTM, ISI, ENEA, ULP, ZEW, Ind., MS

WP4
- EU synthesis Roadmap
- ECN, ISI, ZEW Ind., EC, MS

Ind. - Industry (21 auto, energy/oil and process companies)
MS - regional or member state experts
Thank you for your attention!

For more information about Hydrogen and Fuel Cells please visit

www.HyWeb.de