Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Federal Ministry of Transport, Building and Urban Affairs

Hydrogen: a German Perspective

The National Hydrogen & Fuel cell Innovation Program (NIP)

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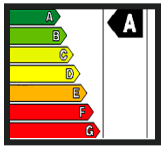
Karlsruhe Institute of Technology

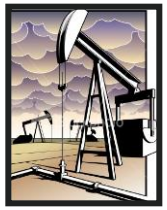
29 September 2008

Requirements of Future Energy Supply

Avoid/ reduce emissions



Increase efficiency



Secure fuel/ energy supply by diversification

Global Competition

Hydrogen and Fuel Cell Technologies offer huge potentials to support these goals!

Status of Hydrogen and Fuel Cell Technology

- Successful demonstration programs ongoing in Germany
- Some systems are already close to commercial applications
- Further **R&D** is necessary for most applications, especially to cut costs
- **Demonstration** is required in order to
  - validate the technology
  - prepare the market environment
- Industry, governments and research join forces to prepare the markets for hydrogen and fuel cell technologies

Political Support

The driving factors for governments to support hydrogen and fuel cell technology are:

- Environmental benefits through reduced or no emissions
- Secure energy supply due to various sources of hydrogen
- Economic growth through innovative technologies

The German National Innovation Programme (NIP) and the European Joint Technology Initiative (JTI) provide the necessary public support

Objectives of the NIP

Use the funds to generate **maximum benefit**, e.g.:

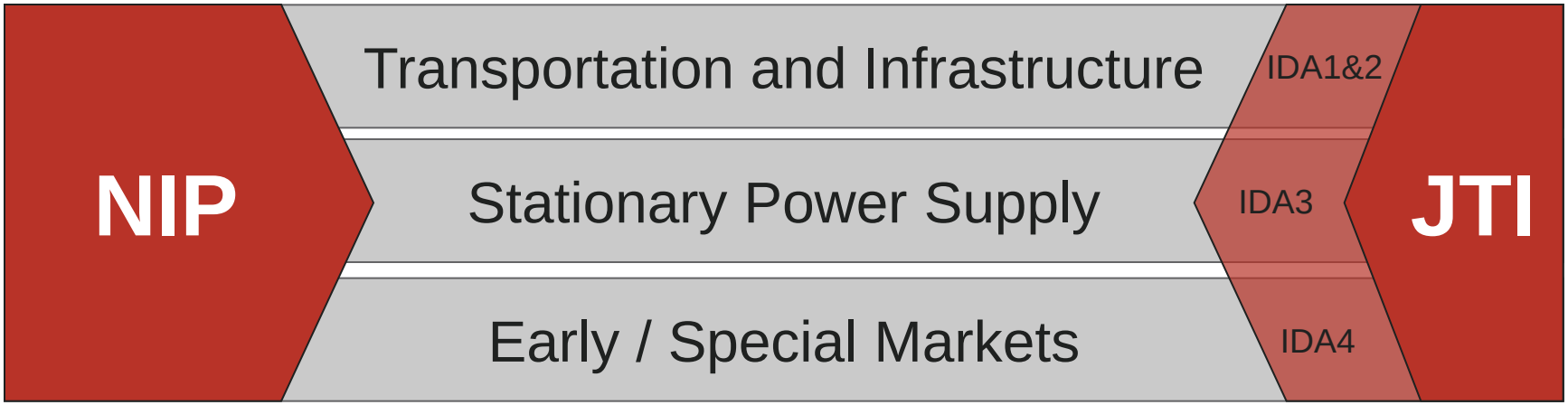
- reduce time to market, create new markets
- make Germany more competitive
- build up high-tech competencies
- create jobs and generate industrial return

… and, **last but not least**:

- conserve energy and combat climate change

Market Preparation Programmes

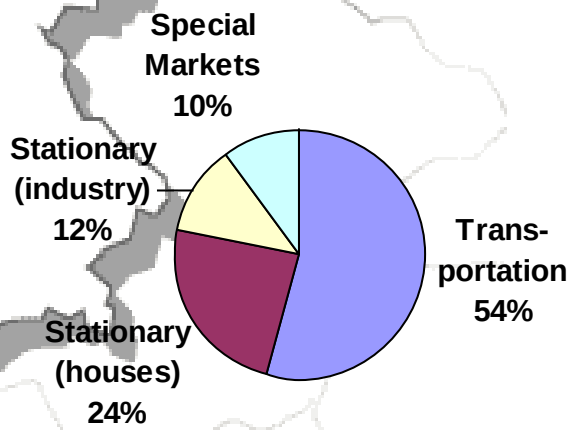
The German National Innovation Programme (NIP) has a similar structure like the European counterpart, the JTI.



The NIP follows the concept of **public-private-partnership**s meaning that industry, research and politics invest in and manage common activities.

National Innovation Program

The German government invests additional 500 mio. € in demonstration activities and the market preparation for hydrogen and fuel cell technology (responsibility: Federal Ministry for Transport, Building and Urban Development) on top of already ongoing R&D programmes (responsibility: Federal Ministry of Economics). Together with the industry investments will add up to more than 1,4 billion € over ten years (2007-2016).

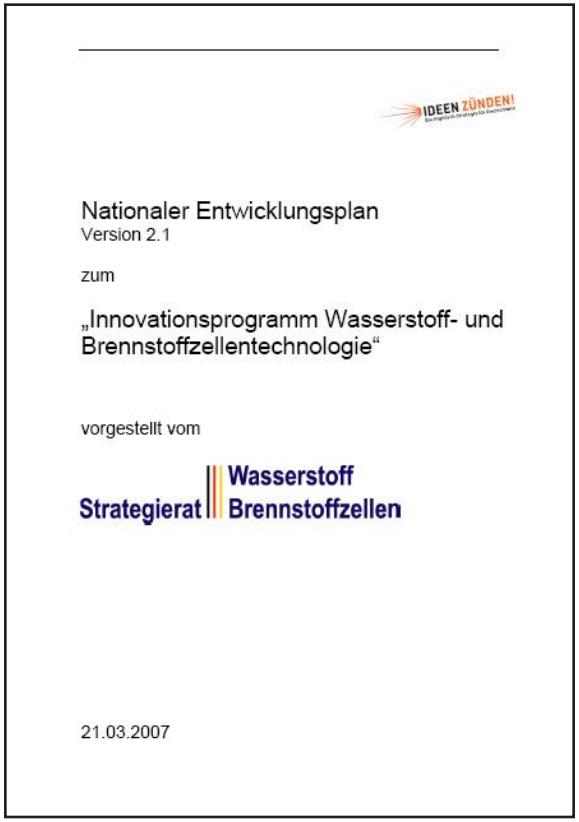


National Development Plan

Politics, industry and science together have defined the necessary steps for the implementation of the NIP in the National Development Plan.

Content:

- Development Plans for
  - Transportation
  - Stationary Home Energy Supply
  - Stationary Industry Energy Supply
  - Special Markets
- Criteria for project funding
- Guidelines for the evaluation of Lighthouse Projects
- Program Management (NOW)


IDEEN ZÜNDEN!

Nationaler Entwicklungsplan
Version 2.1

zum

„Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie“

vorgestellt vom

Strategierat Wasserstoff Brennstoffzellen

21.03.2007

Implementation of the NIP

- Federal government issues mandate to NOW
- Programme described in Development Plan EP2.1
- Responsibility of NOW (www.now-gmbh.de) for the NIP:
  - R&D
  - Demonstration (lighthouse projects)
  - Commercialization
- Administration by project management agency

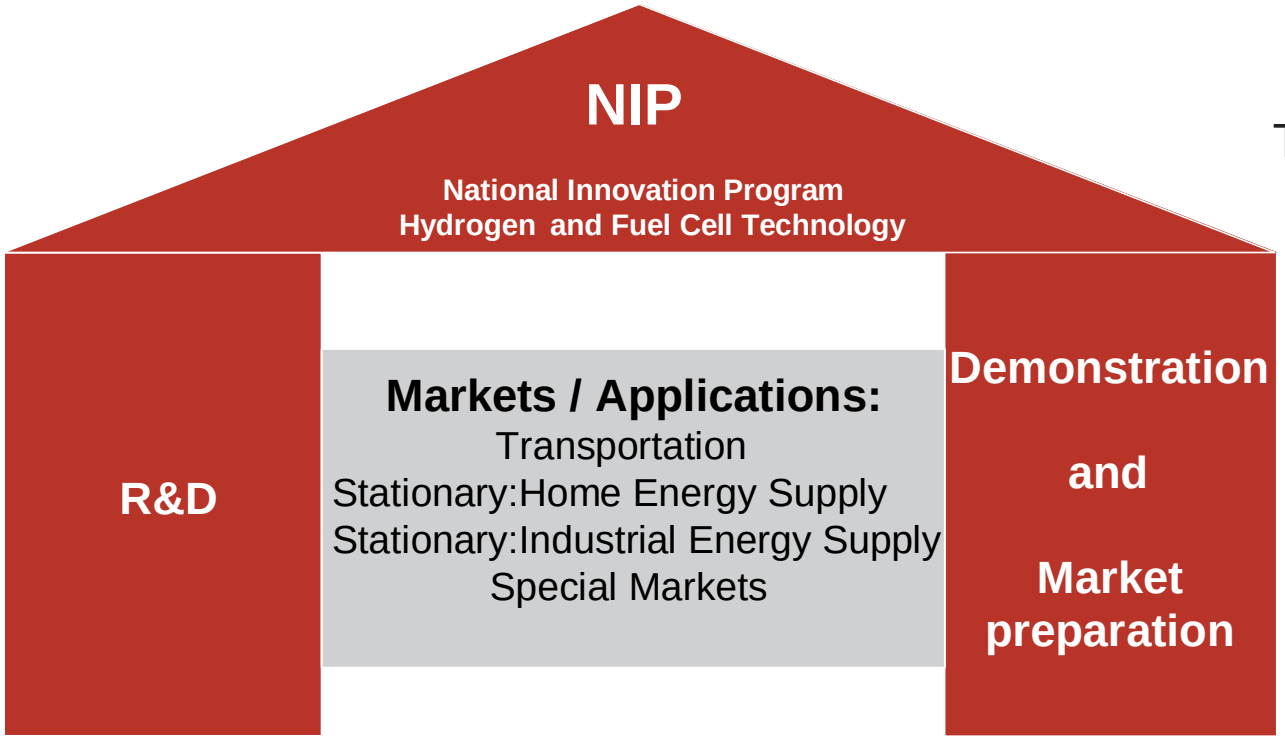
Commitment/ Involvement

OEMs	Suppliers	Research
All major OEMs have programmes for the development and market introduction of hydrogen and fuel cell products.	Partly triggered by OEMs, partly thriving for own new business, many suppliers show hydrogen activities.	The leading research institutes are supporting the industry in further developing the technology.

Energy	Due to the different possibilities for hydrogen production not only oil companies but also energy suppliers and bio-fuel initiatives are involved.

Among the involved parties are encouragingly many SMEs.

German National Innovation Program (NIP)



The NIP is supported by

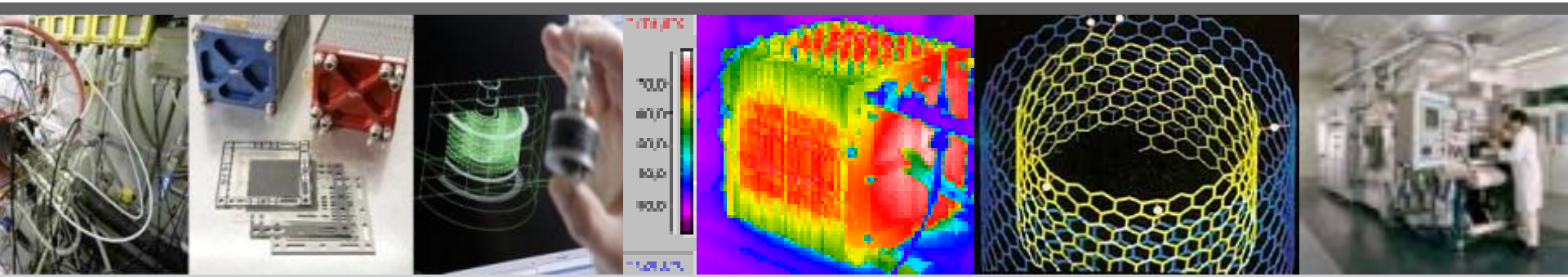
- Federal Ministry of Transport, Building and Urban Affairs
- Federal Ministry of Economics and Technology
- Federal Ministry of Education and Research
- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Roadmap – R&D

Focussed R&D is necessary to:

- Reduce cost
- Increase
  - Lifetime
  - Reliability
  - Efficiency

In Germany a dedicated technology platform will be installed to coordinate the exchange between demonstration and R&D.



Demonstration: Lighthouse Projects

- Basis for market preparation
- Implementation of infrastructure and vendor systems
- Public awareness and visibility
- Confidence in the future of the technology
- Combination of R&D and demonstration
- Frame for suppliers (esp. SMEs)
- Efficient combination of public and private resources

➔ **Strengthen German competitiveness**

Transportation

The transportation industry offers different possibilities to use hydrogen.

Industry is investing heavily in the development of hydrogen and fuel cell related technologies.

Transportation & Infrastructure – Demonstration

OEMs and energy suppliers in Europe have agreed to concentrate on a few demonstration sites (lighthouses) in order to maximise infrastructure usage and visibility at minimised cost.

At most sites primarily busses will be operated, the centre for passenger car demonstration will be Berlin.

Next Steps for the Development of a Hydrogen Infrastructure for Road Transport in Europe

A common position paper of
BMW Group, DaimlerChrysler AG, Ford Motor Company, General Motors Europe AG, MAN Nutzfahrzeuge AG, Shell Hydrogen B.V., Total France and Volkswagen AG

Securing a long-term independent sustainable energy supply is an important strategic goal for Europe. Therefore, special attention by governments, OEMs and the energy sector has been given over the last few years to the introduction of hydrogen as a fuel for road transport. What is needed now is a concrete near and mid term action plan to ensure that development and deployment of hydrogen vehicles and infrastructure in Europe will progress in an aligned way and more quickly in order to allow the beginning of commercialization of hydrogen vehicles around 2015 (or earlier). In this context, different infrastructure needs for passenger cars aiming at mass-market roll-out compared to captive fleets (e.g. city buses) need to be taken into account. The authors of this paper perceive these goals and the resulting actions as a possible first milestone for the installation of a hydrogen infrastructure in Europe.

Based on current knowledge, we anticipate that the further roll-out of hydrogen vehicles will happen in 3 phases:

Phase I until 2010: Technology Development and Cost Reduction.
Bundling of hydrogen demand for cars to one pilot region in Europe for testing higher volumes of cars in order to allow to determine whether we are moving towards acceptable hydrogen cost in relation to future large scale production.

Phase II from 2010 to approx. 2015: Pre-commercial Technology Refinement and Market Preparation.
An interim milestone is to offer in Phase II a hydrogen refuelling station infrastructure (700 bar CGH_2 and LH_2) of sufficient density for cars (publicly accessible and integrated into conventional stations) in one European pilot region and for city buses in a few selected European cities/regions with refuelling stations in dedicated depots to ensure customer convenience and to create and test consumer acceptance.

Phase III starting around 2015: Commercialisation. Ramp-up of production leading to mass production within at least 10 years for every OEM.

Realizing that the companies involved all have their own specific timelines, the timing of these phases represents a minimum consensus. Depending on various influencing factors, the commercialization of hydrogen and fuel cell vehicles may occur even earlier.

In order to allow the effective build-up of a mini-network of hydrogen refuelling stations, the pilot region for passenger cars should meet a set of technical, legal and political criteria which are partly also valid for city buses. These are for example an existing hydrogen infrastructure (filling stations, vicinity to existing hydrogen production and distribution centres), a favourable legislative environment/commitment of the region/country (financial commitment, favourable codes & standards, ease of approvals, low bureaucracy) and the potential for organic growth of the hydrogen infrastructure ("Lighthouse Function" of the region). Based on these assumptions, the following most promising locations/regions have been identified in initial discussions for vehicle deployment and corresponding infrastructure build-up prior to commercialization:

1. LHP (Lighthouse Project) for cars and city buses (one pilot region): Berlin (Germany)

2. LHP for city buses (few selected cities/regions): Hamburg (Germany) which could include synergies with stationary applications and could serve as an extension of the Berlin project, Brussels/Rotterdam (Belgium/Netherlands), Madrid/Barcelona (Spain), South Tyrol (Italy), London (United Kingdom), North Rhine-Westphalia (Germany) and some other locations.

Contributions from additional vehicle manufacturers and infrastructure suppliers are welcome. This should happen on the assumption that the overall goals outlined above are accepted and a short-term return of investment during these pre-commercial technology and market preparation phases is not anticipated, but is the "cost-of-entry" to jointly determine the commercial viability of hydrogen-fuelled vehicles. It should be emphasized, however, that any plans are still in the development phase and no decision has been taken at present on any further specific joint initiatives. Any implementation of such initiatives, including the roll out of joint sites, will be subject to competition law compliance.

Transportation Timeline

All activities aim at preparing the market for hydrogen and fuel cell technology in the transportation sector until 2015.

This includes competitive products, an established infrastructure, well defined legislation and customer acceptance.

To reach this goal all activities have to be coordinated centrally. Especially the exchange between demonstration and research is of importance.

Phase 1 until 2010	Phase 2 2010 - 2015	Phase 3 from 2015
Technology development Cost reduction	Market preparation Technology refinement	Market introduction

Clean Energy Partnership

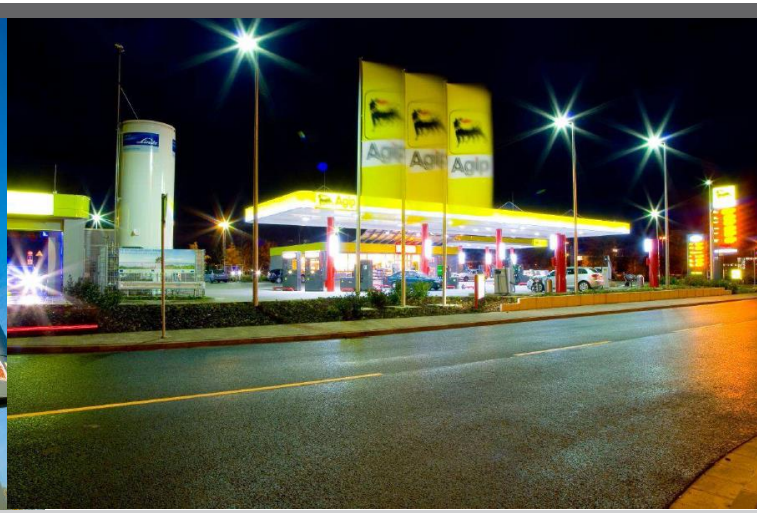
Current status
- Operation of hydrogen and fuel cell cars
- Two hydrogen stations installed

Future plans
- Expand vehicle fleet
- Include bus activities
- Install further hydrogen stations
- Connect Berlin and Hamburg

Zero Regio in Frankfurt

Zero Regio

- In operation since November 2006
- Hydrogen dispenser: 35MPa & 70MPa CGH2, LH2
- Pre-cooling: -28° C (-15° C at nozzle)
- Flow rate: 60g/sec
- Fill time: 3kg in less than 3 minutes
- Ionic Compressor installed
- Maximum hydrogen pressure: 85MPa
- IR-Communication interface in preparation
- Photovoltaic system: 78m², 8kW



Industry Commitment Example: Daimler

Generation 1
Technology Demonstration

- High efficiency
- Zero/ultra low emissions
- Low noise
- High driving comfort
- Performance, package & weight
- Use of alternative fuels
- New innovative vehicle concept
- Basic demonstration of customer benefits

2004

Generation 2
Customer Acceptance

- Higher stack lifetime of 2000h
- Increasing of power (65kW⇨100kW)
- Higher reliability
- Longer range (160km⇨400km)
- Freeze start ability
- Li-Ion battery
- Decrease component costs

2010

Generation 3+4
Cost Reduction + Market Introduction

- Minimized humidifier respectively no humidifier
- New compressor generation
- Improved fuel cell stack
- Optimized air module
- Simplified H2 loop
- Improved operating strategy
- Simplified anode module

2013

Generation 5
Mass Production

Vehicle Ready for Mass market
- Smaller stack
- More power
- More torque
- Better fuel (equivalent) efficiency
- Excellent cold start ability

2020

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2020

Industry Commitment Example: BMW

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Technology Demonstration

- High efficiency
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2020

Industry Commitment Example: General Motors

GM has years of experience with fuel cell vehicles.

GM's current product, the Equinox offers:
- 73 kW
- 160 km/h top speed
- 4,5 kg CGH2
- 320 km range

OEMs all over the world develop fuel cell vehicles

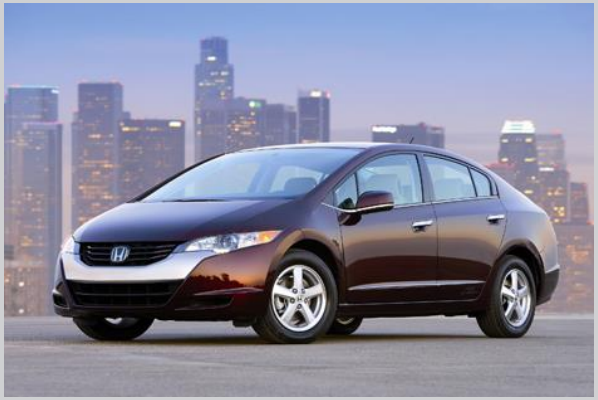
Hybrid pioneers Honda and Toyota have vivid fuel cell car programmes

Toyota FCHV 70 MPa

90 kW PEM fuel cell stack,
hybrid with Ni MH battery;
range 560 km

Honda FCX Clarity

new PEMFC developed
by Honda: 100 kWe
range ~ 430 km



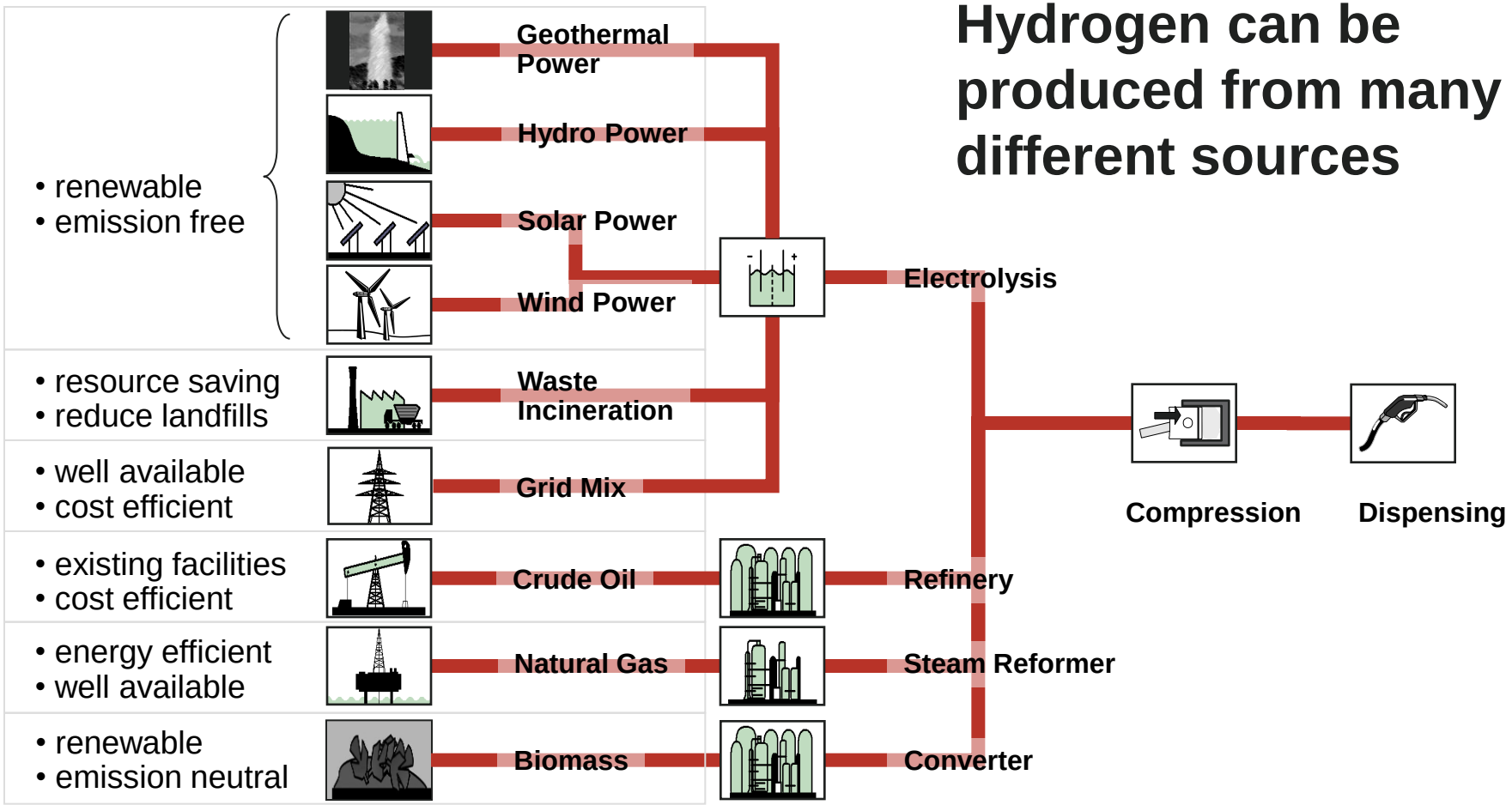
Most OEMs are also active in fuel cell technology, e.g.:

Chery - Eastar FCV

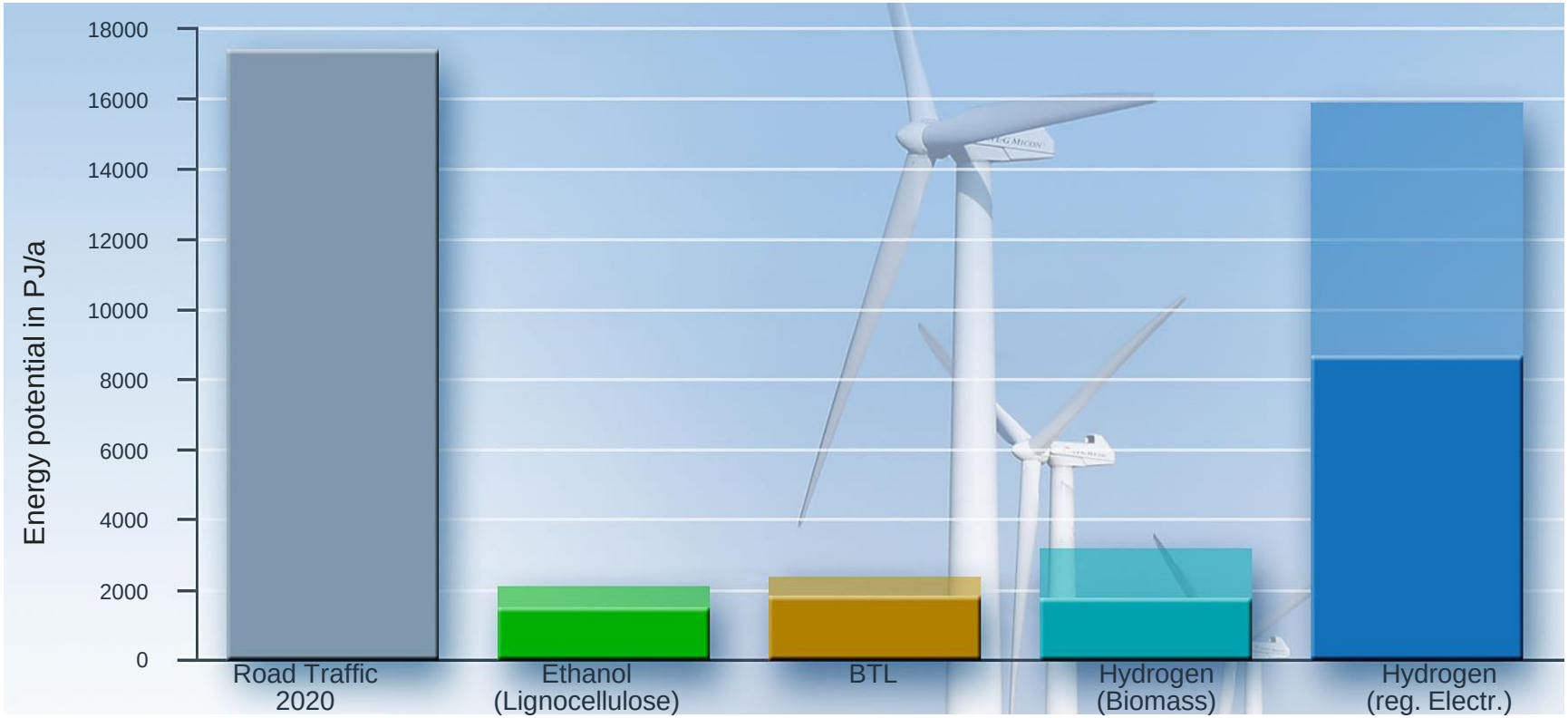
Hyundai Tuscon Hydrogen Car

Infrastructure: Hydrogen Production

Hydrogen can be produced from many different sources



Potential of Hydrogen for European Road Traffic



Source: TES (Transportation Energy Strategy) Report 2007

Lighthouse Industrial Power Generation

60 biogas systems

- High temperature fuel cell, 200-700 kW
- Combined with gas washer, ORC, heat usage
- Cooperation of fuel cell and biogas system manufacturers with operators and energy suppliers

Industry has accepted the opportunities that hydrogen and fuel cell technology offers.

Lighthouse Home Energy Supply

- Cooperation of well known manufacturers of heating technology, energy suppliers, research institutes and users
- Installation von more than 600 systems in 3 - 5 German regions
- Deployment of synergies through cooperation in demonstration, development, RCS, qualification and communication

Fuel cell based home energy supply is a chance for both users and industry.

Special Markets

Special Markets have a key role within the NIP.

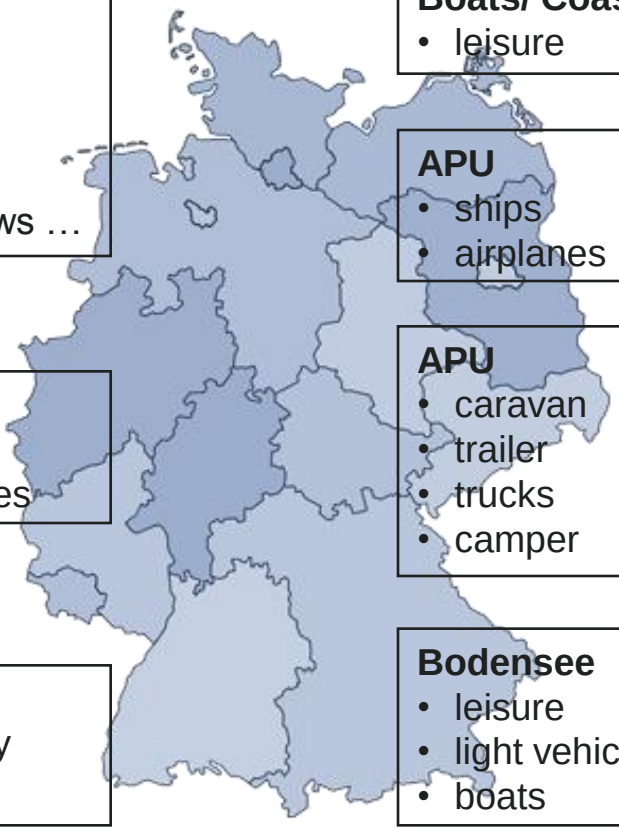
- Early market opportunities especially for the supply industry
- Create Public acceptance and visibility

Material Handling
- forklifts
- industrial trucks
- etc.

For manufacturing airports, trade shows …

Special Vehicles
- Cargo bikes
- Municipal vehicles

USV
- mobile telephony
- railroad



Boats/ Coast
- leisure

APU
- ships
- airplanes

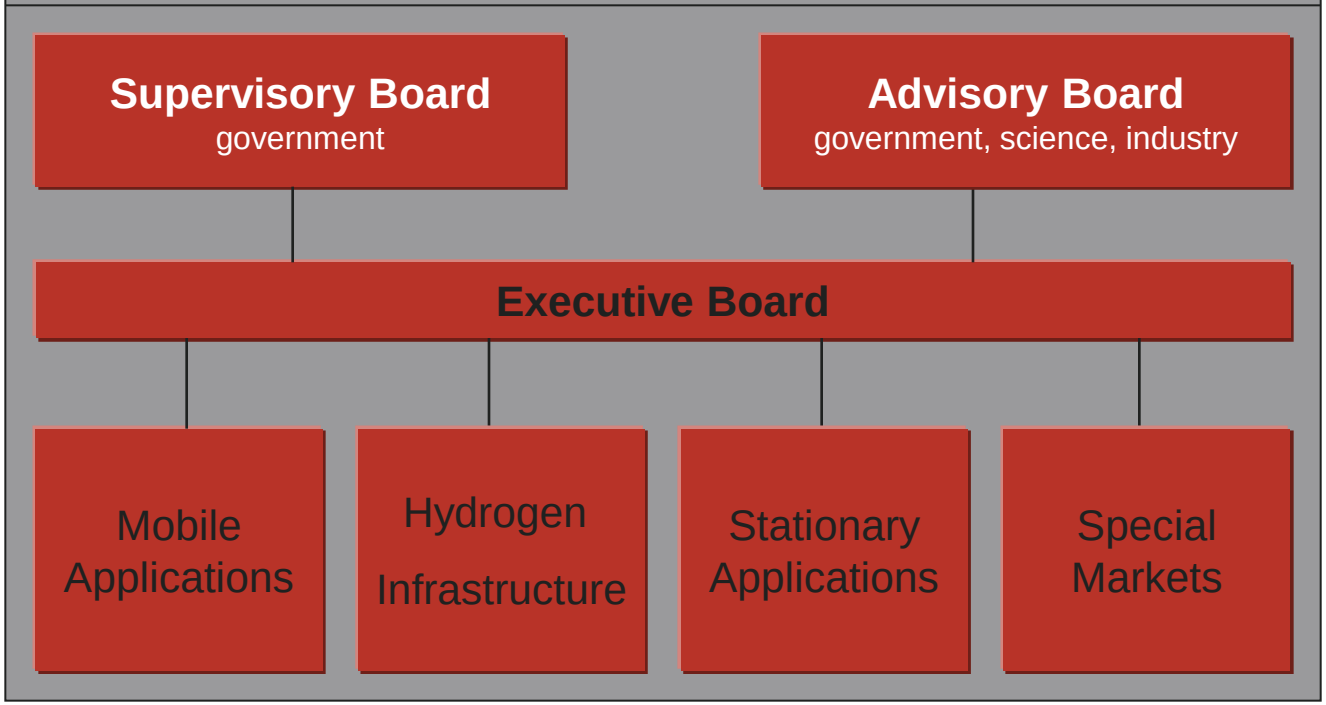
APU
- caravan
- trailer
- trucks
- camper

Bodensee
- leisure
- light vehicles
- boats

NOW

National Organisation Hydrogen and Fuel Cell Technology

Shareholder:
German Federal Government (100%)
Represented by the Federal Ministry of Transportation, Building and Urban Affairs



Conclusion

Hydrogen and fuel cell technologies contribute to future energy requirements.

Emissions	Fuel cells in combination with hydrogen based on renewable energy sources are emission free
Efficiency	Fuel cells are more efficient than most other energy conversion devices
Energy portfolio	Different sources of hydrogen broaden the primary energy portfolio significantly and offer regional opportunities

Germany is a major driver for hydrogen and fuel cell technology in Europe