Hydrogen and Fuel Cell Activities in Germany

WICaC

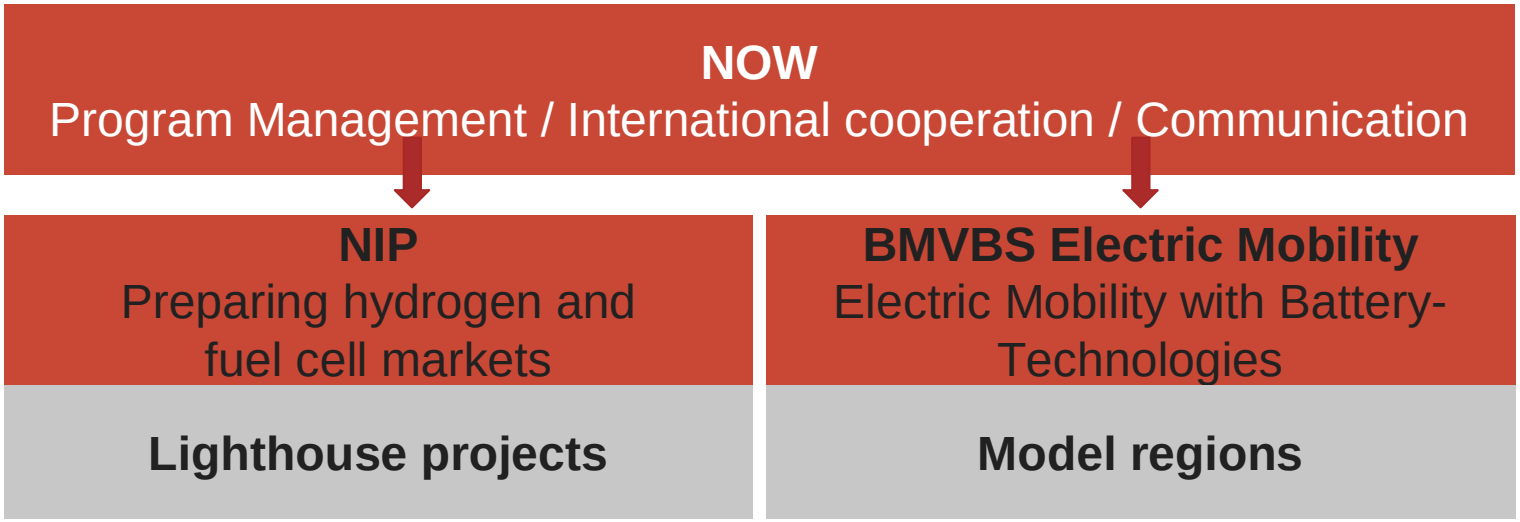
6th International Workshop on Hydrogen and Fuel Cells
Campinas | Brazil

October 3-5, 2012

Dr. Klaus Bonhoff | Managing Director (Chair)
NOW GmbH National Organization Hydrogen and Fuel Cell Technology

NOW GmbH
National Organization Hydrogen and Fuel Cell Technology

- Government-owned company (100 %) founded in 2008
- Co-financing by industry (project overheads)
- Supervisory board: BMVBS (Chair), BMWi, BMBF, BMU
- Advisory board: strategic controlling and development of programmes



programmes addressing market preparation

Preparing Hydrogen and Fuel Cell Markets: National Innovation Programme (NIP)

Politics	Industry

BMVBS / BMWi / BMBF / BMU

500 million € for demonstration + **200 million €** for R&D + **700 million €** Co-payment from industry

1,4 billion €
2007-2016

- 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

National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP)

Preparing Hydrogen and Fuel Cell Markets

Transportation (54%*)

- H_2 production and infrastructure
- Expanding vehicle fleets and hydrogen infrastructure starting from key regions

Stationary Applications (36%*)

- Micro CHP for residential use
- Industrial gensets for CHP and trigeneration

Special Markets (10%*)

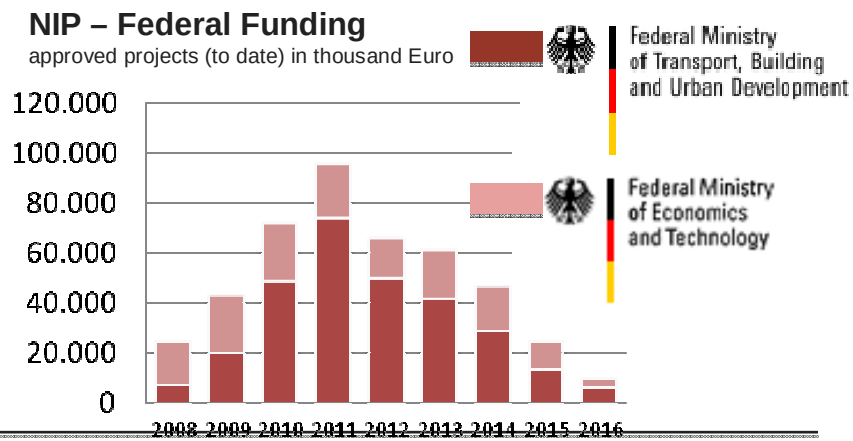
- IT, telecommunications
- Logistics, leisure and tourism markets

* distribution according to the National Development Plan

National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP)

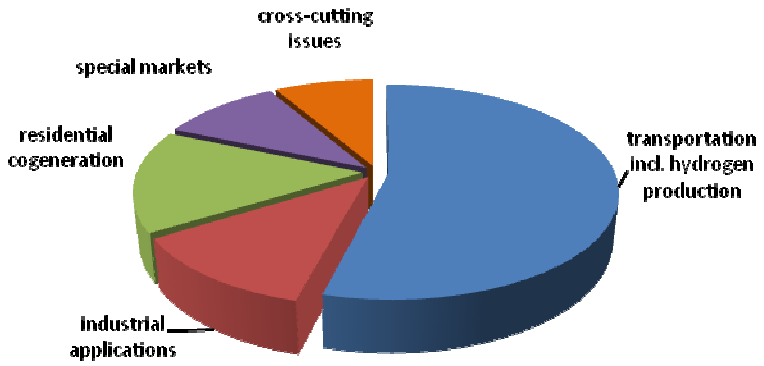
Successful R,D&D-Programme

- link R&D with demonstration
- multi annual framework (2007-2016)
- collaboration of politics, industry and academia
- market driven
- central programme-management and networking structure



programme area	# projects	# partner	funding BMVBS	funding BMWI	NIP total
transportation incl. hydrogen production	112	220	186.159	74.319	260.478
industrial applications	37	70	31.451	26.325	57.776
residental co-generation	26	92	38.888	35.287	74.175
special markets	50	95	38.547	10.209	48.756
cross-cutting issues	28	62	11.528	28.662	40.190
Total	**253**	**539**	**306.572**	**174.802**	**481.374**

(budget figures in thousand Euro)



The NIP – Programme Area Stationary Residential Applications

callux (nip)
Praxistest Brennstoffzelle fürs Eigenheim
Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie

on, Staxera, Vaillant, EnBW

- **Objective**: High-efficient co-generation for residential applications
- 1 Lighthouse-Project: CALLUX: Start Sept. 2008
  - 5 utilities, 3 appliance suppliers, science and craftsmanship
  - Budget approx. 80 Mio € for 800 units to 2015 (Status today: 207 units)
- 7 further Projects with SOFC, LT-PEM, HT-PEM
- 1 R&D project “Desulphurisation Standard”

Project goals

Launch of natural gas-driven fuel cell heating appliances to be prepared

- Demonstrate technical maturity, support further improvements to ensure marketable products
- Develop supply chains by winning binding orders for large numbers
- Enhance product profile on the market
- Continue work on concepts for supply structure integration
- Support (further) training of market partners
- Validate requirements against customers and the market
- Promote the creation of added value in Germany

Examples

Single-family home in Westoverledingen
(Lower Saxony)

Single-family home in Oldenburg
(Lower Saxony)

Baxi Innotech fuel cell heating appliance: GAMMA 1.0

CHP section

Type	low-temperature PEM fuel cell (70 ℃)
Output (e/th)	max. 1.0 kWe/1.7 kWth
Modulation range	approx. 100 – 30% PeN
Fuel	natural gas, biomethane
Electrical efficiency (NCV)	32%
Total CHP efficiency	> 83%

Integrated auxiliary heater

Type	condensing appliance
Output	3.5-15 kW or 3.5-20 kW
Efficiency	109% (ηN at 40/30 ℃)

Complete system

Total efficiency	> 95% (to EN 50465 with 60/40 ℃ fl ow/return)
Dimensions (mm)	600 long x 600 wide x 1,600 high
Weight	approx. 230 kg
Housing	coated, fully enclosed
Natural gas pressure	20/25 mbar (EN 437)
Electrical connection	230 V/50 Hz
Operating mode	power-controlled, heat-controlled, energy manager-controlled; central control (virtual power plant)

Hexis fuel cell heating appliance: Galileo 1000 N

CHP section

Type	solid oxide fuel cell (SOFC)
Output (e/th)	1.0 kWe/2.0 kWth
Modulation range	100-50%
Fuel	natural gas, biomethane
Electrical efficiency (NCV)	> 30-35%
Total CHP efficiency	> 92%

Integrated auxiliary heater

Type	condensing appliance
Output	4-20 kW
Efficiency	109% (ηN at 40/30 ℃)

Complete system

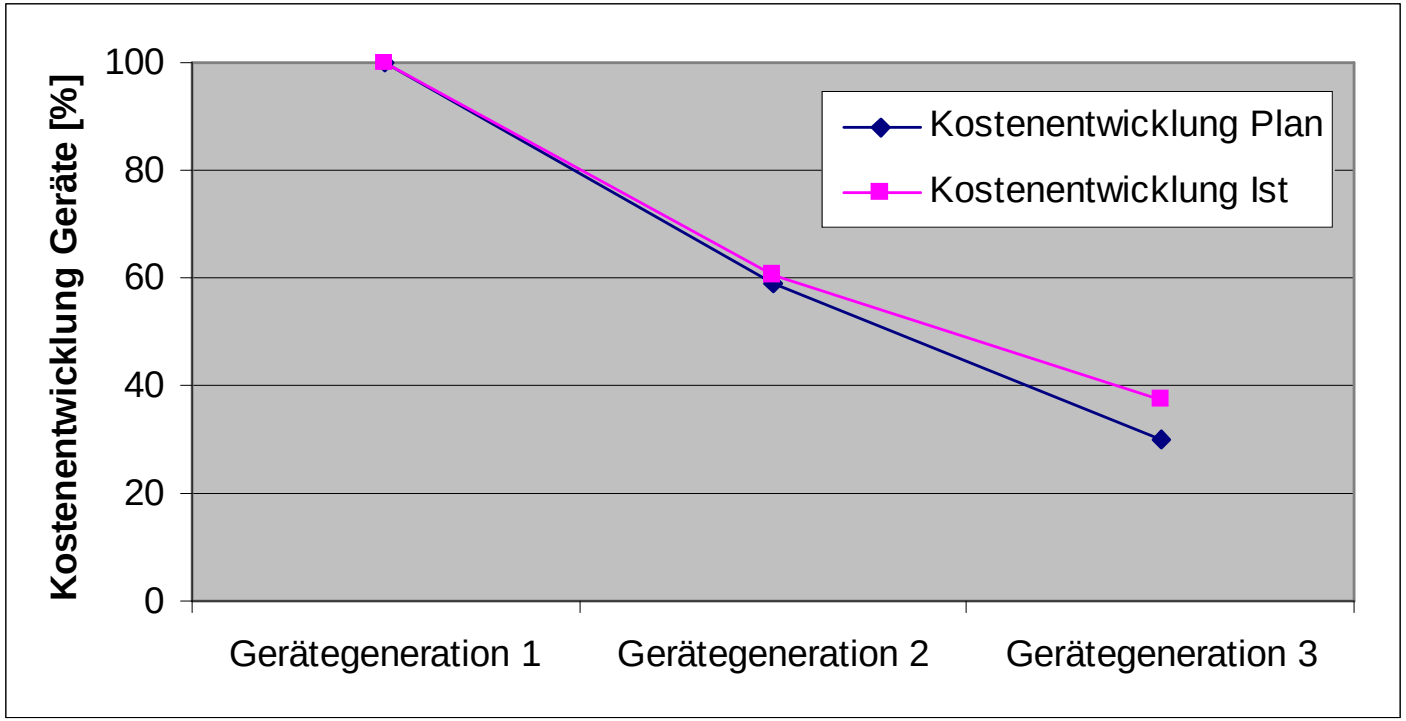
Total efficiency	> 95% (to EN 50465 at 60/40 ℃ flow /return)
Dimensions (mm)	550 long x 550 wide x 1,600 high
Weight	approx. 170 kg
Housing	coated, fully enclosed
Natural gas pressure	20-25 mbar (EN 437)
Electrical connection	230 V/50 Hz
Operating mode	heat-controlled, energy manager-controlled; remote control option

Vaillant fuel cell heating appliance

(Technical target values)

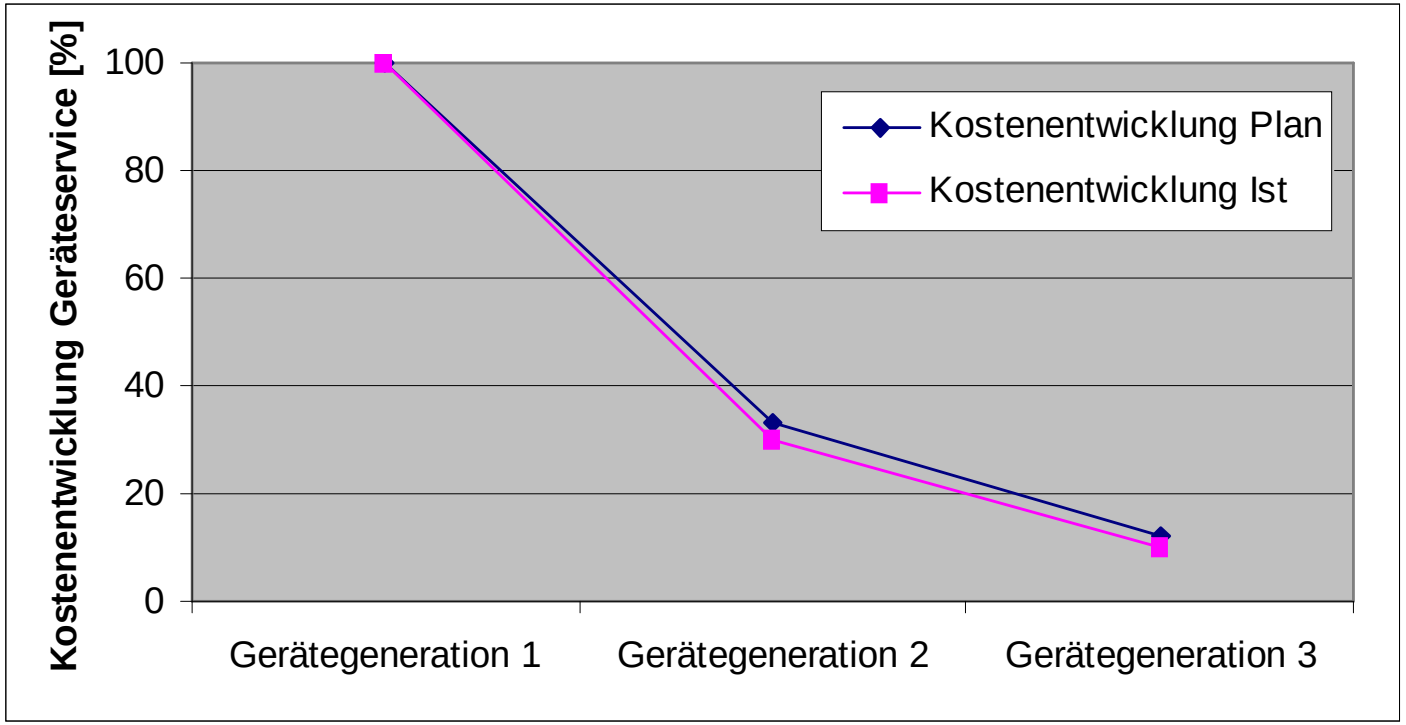
Type	solid oxide fuel cell (SOFC)
Output (e/th)	max. 1.0 kWe/2.0 kWth
Application	single-family home
Fuel	natural gas, biomethane
Electrical efficiency (NCV)	30%
Total CHP efficiency	80 – 85%
Appliance data	
Dimensions (mm)	600 long x 625 wide x 986 high
Weight	approx. 150 kg
Housing	coated, fully enclosed
Natural gas pressure	20-25 mbar (EN 437)
Electrical connection	230 V/ 50 Hz
Operating mode	heat-controlled, energy manager-controlled; remote control option
External peak heater	
Type	condensing appliance
Output	configuration as required by user
Efficiency	109% (ηN at 40/30 ℃)

Development costs fuel cell heaters
(average of all manufacturers)



→ During the project, the equipment cost were reduced by about 60% so far.

Cost development service / spare parts
(average of all manufacturers)



→During the project, the costs of equipment service and spare parts can be reduced by about 90%.

The NIP
Marine Applications

Sources: NOW, Calypso/Aida, e4ships, CMT

- **Goal**: Emission reduction of hotel and harbour operations
- **Application**: electricity, heating, cooling supply; tank-inertisation
- Ferry, yacht, research und trade vessels;
  navy vessels supposed to follow
- Fuels: Sulfur-free diesel, XTL, H2

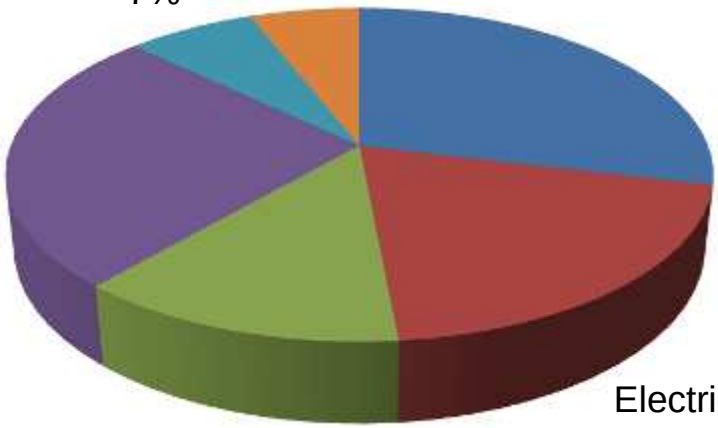
Fuel Cell Power Plants in Industrial Applications

Source: FCE, 2011

The NIP – Programme Area Special Markets

Individual projects 6%

Micro fuel cells 7%



Electricity supply in business applications 29%

Materials handling, special purpose vehicles 26%

Light electric vehicles 13 %

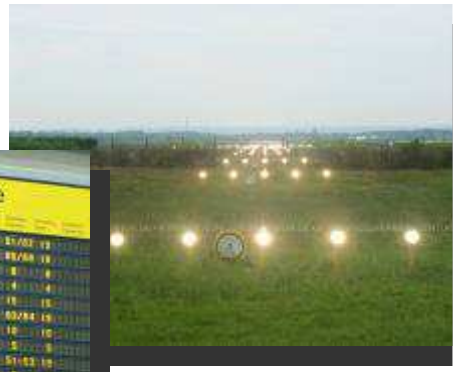
Electricity in leisure markets 20%

The NIP – Programme Area Special Markets
Energy-Supply for Airports – a possible market!

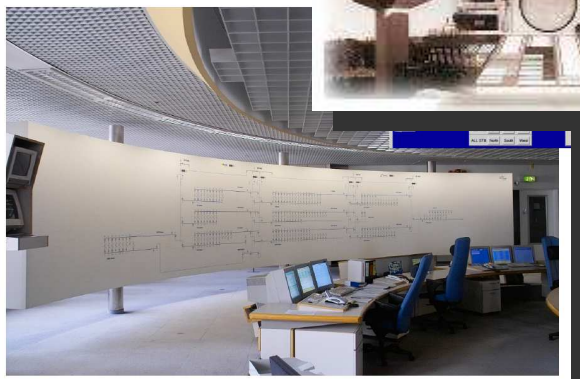
GPU

Ground Handling

PAX-Transportation

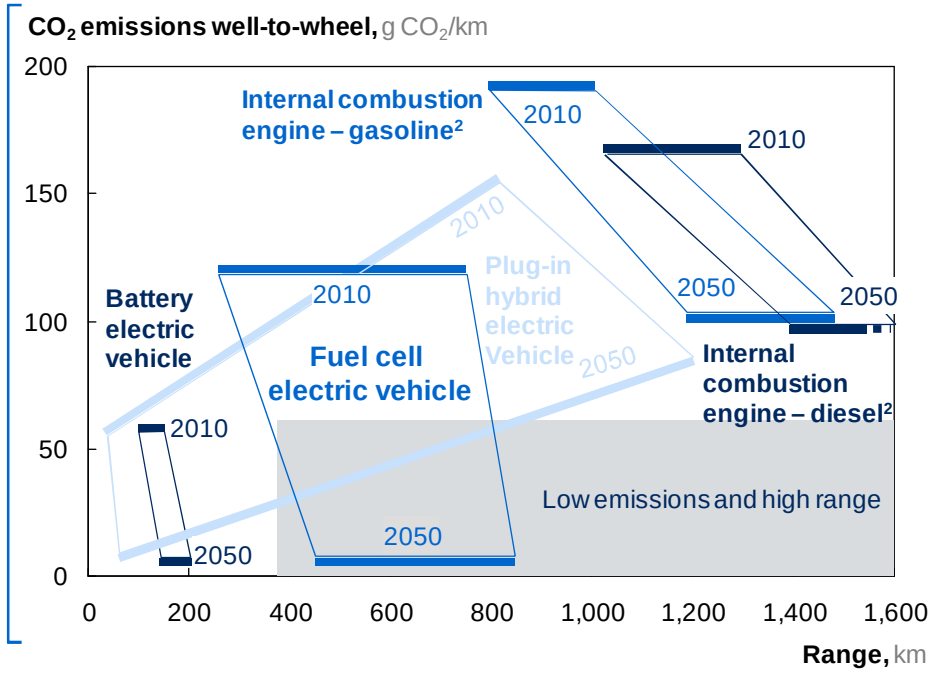


UPS

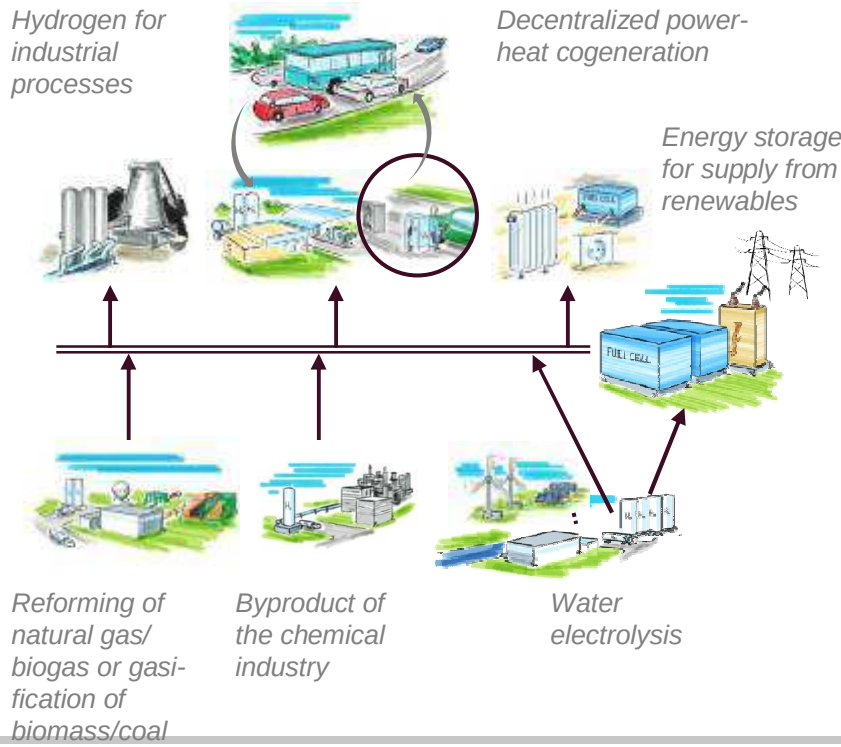


Fuel Cell Vehicles and Hydrogen from Renewable Energy Sources are Key Elements of an Integrated Sustainable Energy System

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**

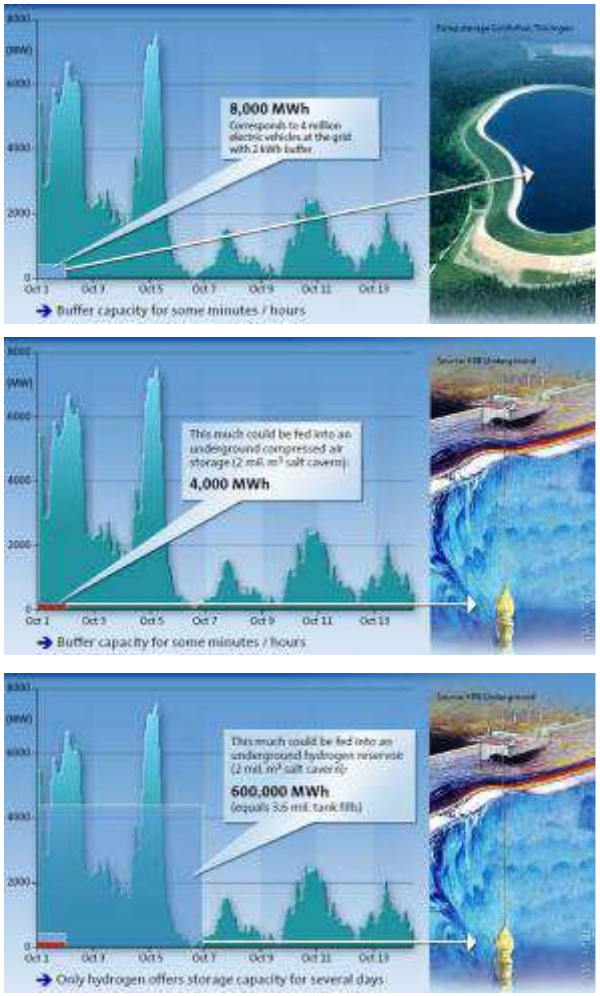


Hydrogen:
Storing Energy from Large Renewable Power Sources

Increasing the share of renewable power (esp. wind) requires:
- optimized expansion of the power grid
- „Smart Grid“ technologies
- storage

Hydrogen stores large amounts of energy over longer periods of time.

Once produced hydrogen can be used as a fuel in the transportation sector.



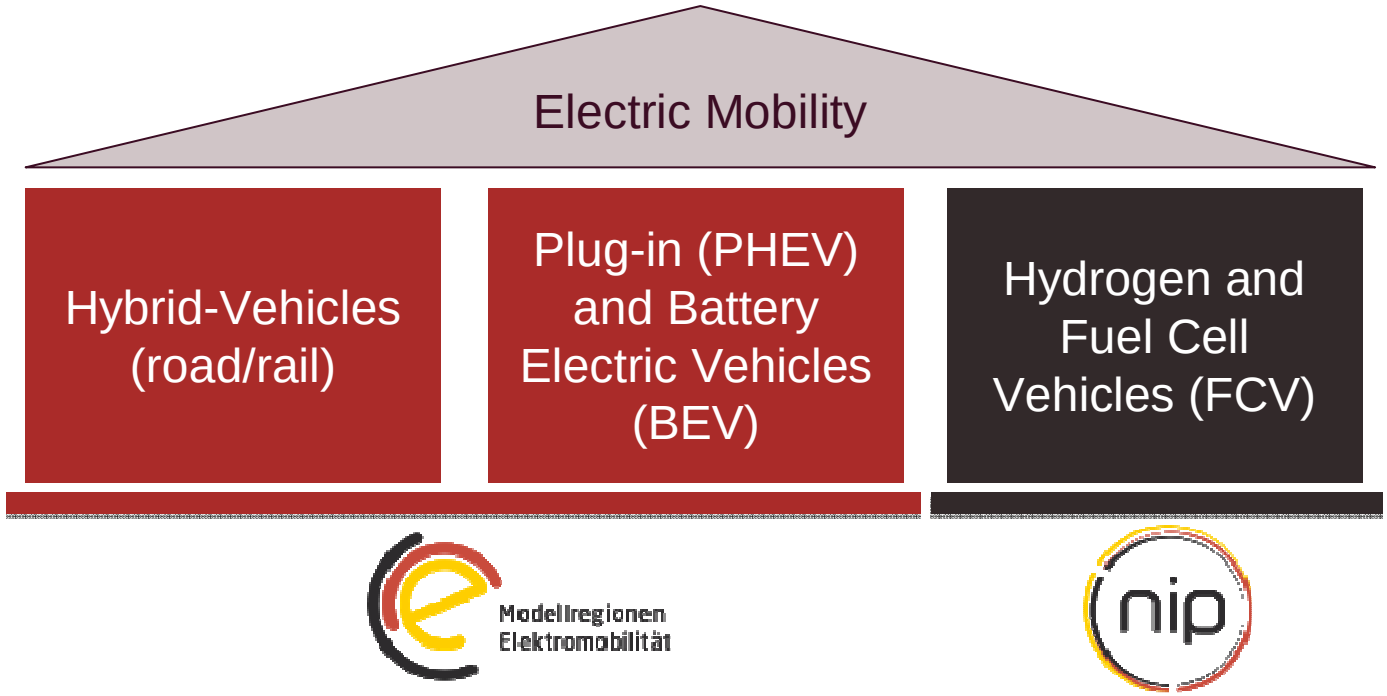
source GM/Opel

Programs for Market Preparation of Electric Mobility

The governmental E-mobility activities strive for electrification based on three major pillars

Powertrain electrification:

- increases efficiency
- has potential for CO_2-free mobility



Electrification relies on the key technologies of battery-electric and fuel cells

Supply chain for hydrogen-carrying components of fuel cell systems

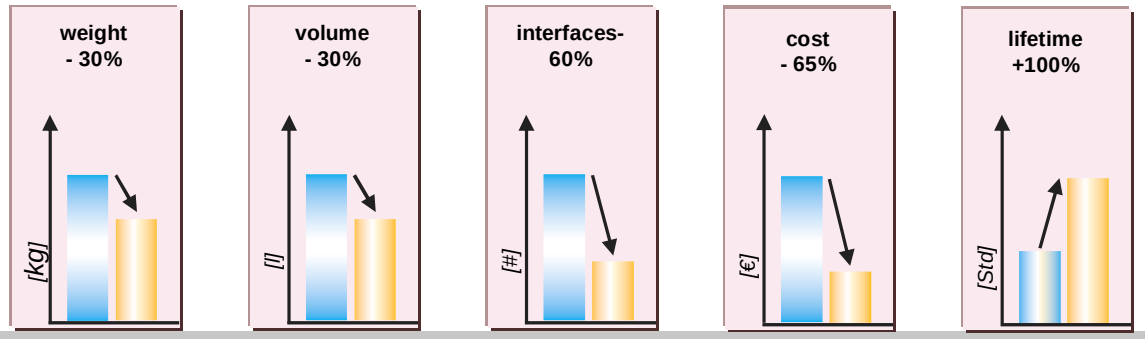
Anode Gen2

- simplify module
- higher degree of integration

- reduction of the components
- easier installability
- optimized manufacturing processes

Anode Gen3

expected improvements



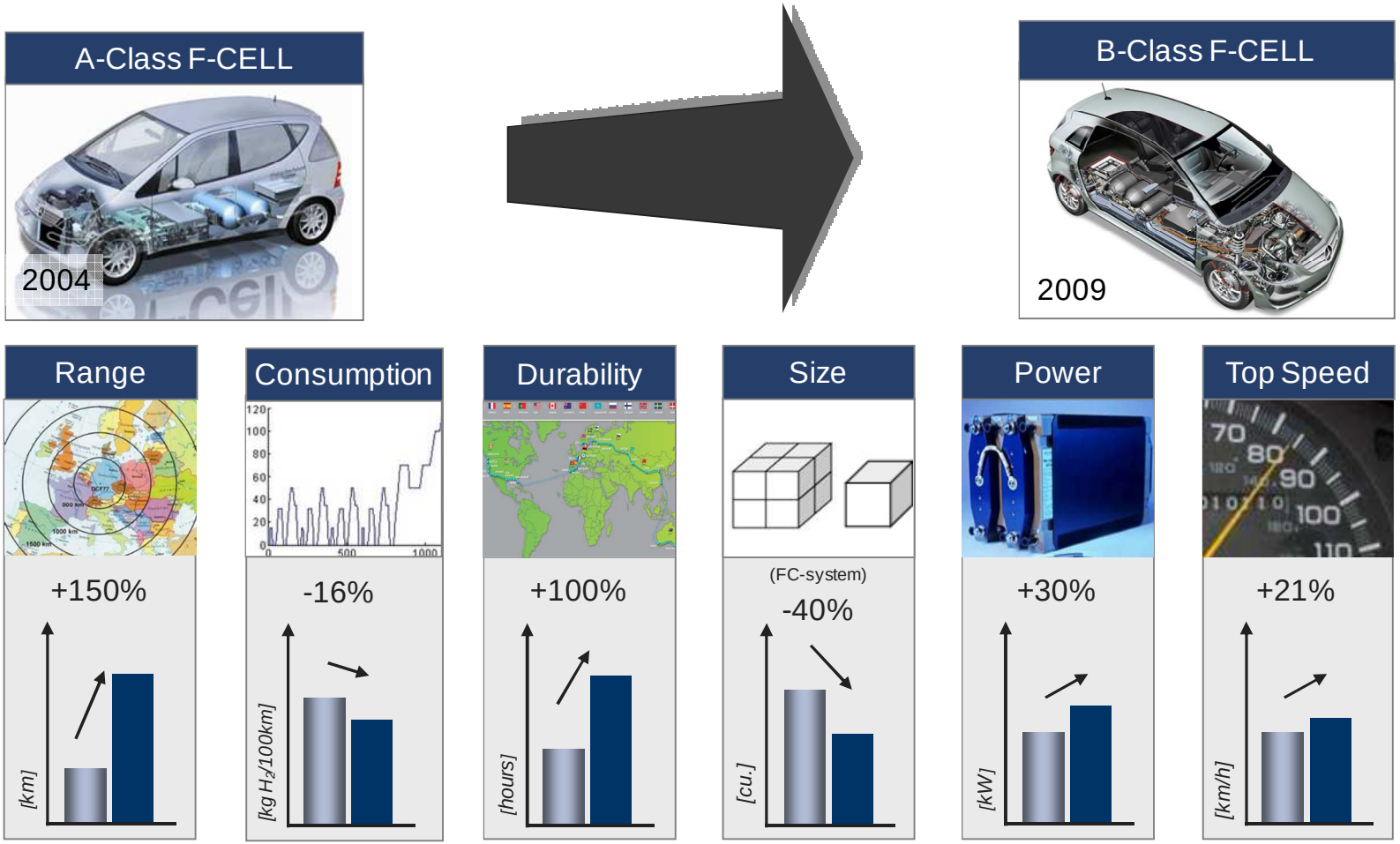
Fuel Cell System Design Evolution
e.g. GM/Opel

Fuel Cell System Design Evolution

	HydroGen4	Next Generation
		
Net power	93 kW	85-92 kW
Max excursion temp	86°C	95°C
Durability	1,500 h	5,500 h
Cold operation	Start from -25°C	Start from -40°C
Mass	240 kg	< 130 kg
Sensors / actuators	30	≤ 15
Stack subsystem: Plates UEA	Composite 80 g platinum / FCS	Stamped stainless steel < 30 g platinum / FCS
Air subsystem & humidification	Tube-style humidifier Sensor-based RH control	GM designed humidifier Model-based RH control
Design integration	Semi-integrated	Highly integrated for thermal performance

GM APCE

Technical Advancements of Fuel Cell Electric Vehicles



Clean Energy Partnership – FCV Fleet

Planned fleet of Fuel Cell Vehicles by the end of 2012

- 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 has recently joined the CEP
- 7 Fuel Cell Busses (Evobus) in Hamburg

Clean Energy Partnership – Hydrogen Refueling Stations (HRS)

Hamburg, Bramfelder Chaussee Shell

Hamburg, HafenCity Vattenfall/ Shell

Hamburg, Cuxhavener Str. Total

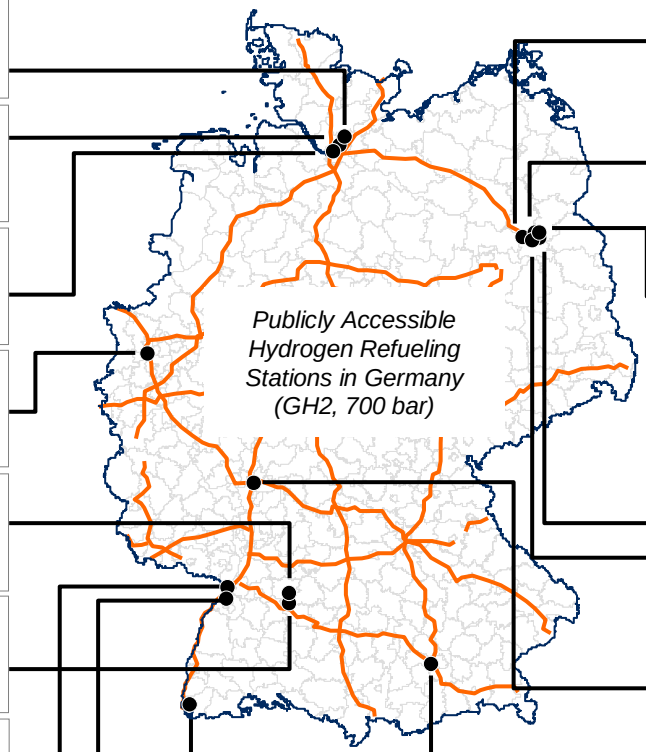
Under construction — **Düsseldorf**, Air Liquide

Under construction — **Stuttgart**, EnBW

Stuttgart, Airport OMV

Karlsruhe, ENBW

Under construction — **Karlsruhe**, KIT



Freiburg, FhG ISE

Berlin, Heidestraße Linde/Total

Berlin, Heerstraße Total

In planning stage — **Berlin**, BBI Total

Berlin, Holzmarktstraße Linde/Total/ Statoil

Berlin, Sachsendamm Shell

Frankfurt (Höchst), AGIP

Munich, Detmoldstraße Total *(only LH2)*

Key achievements

- Safety of stations proven
- Refueling standards agreed
- Storage and compressor technology tested
- H_2 supply chain tested
- Bugs of station technology eliminated

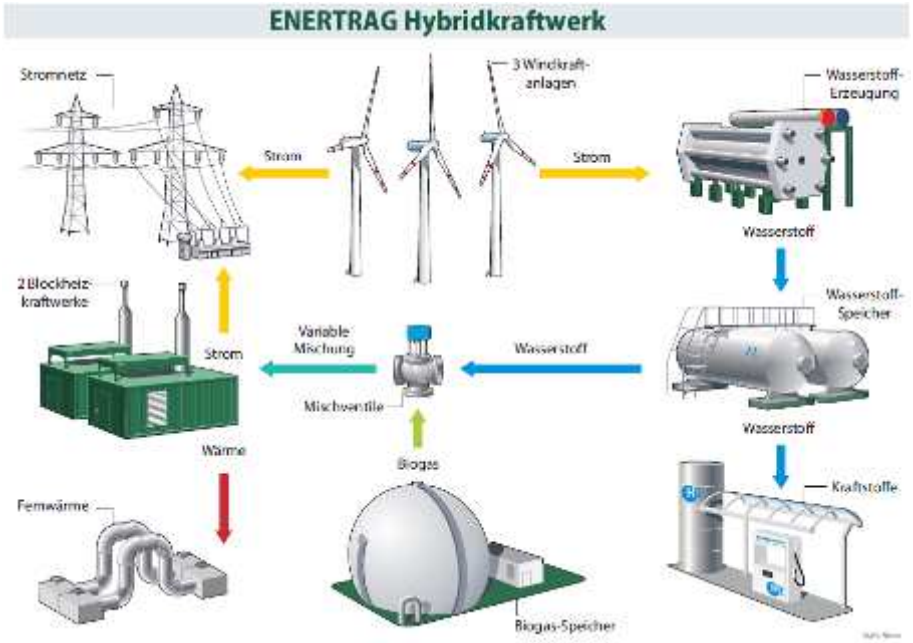
- Several additional stations are currently planned

– Daimler and Linde have announced to build 20 HRS within the next years

– The German Government has announced 50 stations until 2015

Demonstrating Wind-Hydrogen for Mobility

hydrogen as part of an integrated energy system ⟹ renewable hydrogen as fuel



Enertrag: Hybrid Power Plant

Total: Refueling Station at Heidestr., Berlin
First delievery of wind-hydrogen on April 18th, 2012

Strategy for Production of Hydrogen Fuel: Focus on Wind und Biomass

vast expansion of **wind power** capacities turns wind into **main source of energy for H_2 production** after 2020

- demonstration of wind H_2 systems required
- key technology **electrolyses** in MW range
- improvements in efficiency & costs needed
- **studies show great potential** of **wind H_2 systems** for **leveling out fluctuating energy**
- NOW demonstration projects, workshops and studies

also **biomass** important for H_2 production as of 2020

– especially **gasification processes**

– NOW demonstration projects and studies

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)**

Federal Ministry of Transport, Building and Urban Development

CEP

Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie

nip

NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

„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

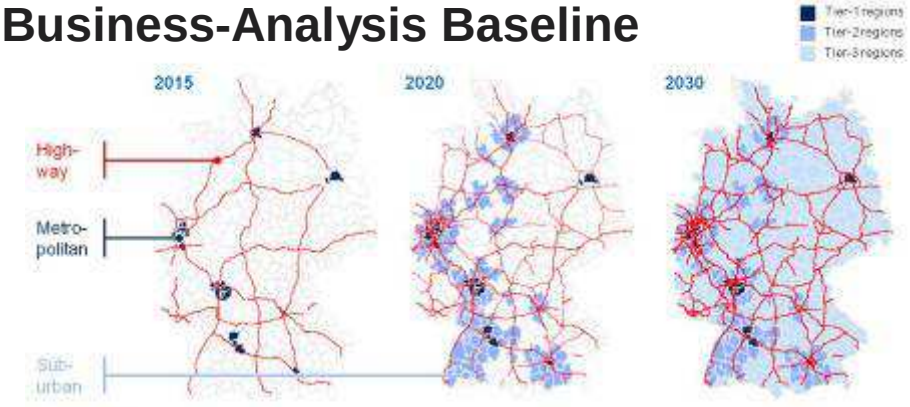
Preparing for a Hydrogen Infrastructure in Germany

H_2 Mobility

H_2 Mobility analysis participants in 2011

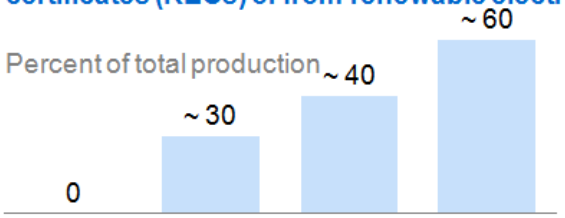
DAIMLER, TOYOTA, NISSAN, TOTAL, VATTENFALL, EnBW, GM, BMW GROUP, Intelligent Energy, OMV, Linde, AIR LIQUIDE, SIEMENS, HYUNDAI, KIA MOTORS, NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie, AIR PRODUCTS

Business-Analysis Baseline

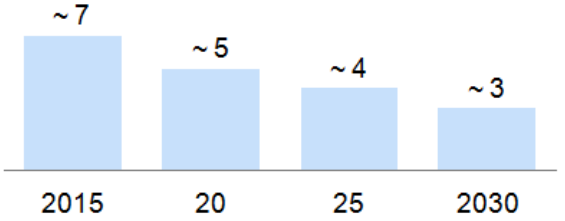


	2015	2020	2030
No. of FCEVs Thousands	~ 5	~ 150	~ 1,800
No. of HRS	~ 100	~ 400	~ 1,000
Total population covered by HRS Percent	~ 20	~ 60	~ 100

Water electrolysis with renewable energy certificates (RECs) or from renewable electricity



H_2 production mix CO_2 footprint



NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Phased approach to a profitable commercial infrastructure ramp-up

	R&D and demonstration	market preparation and validation	commercial ramp-up
When? Who?	▪ Since 2006 ▪ CEP/NIP	▪ For the next 5 - 10 years ▪ H2 Mobility and CEP/NIP	▪ Around 2020 ▪ H2 Mobility and free market
Goals	▪ HRS technology up and running ▪ Costs significantly reduced	▪ Proof of HRS, FCEV technology, and H_2 supply chain ▪ Customer acceptance of FCEVs ▪ Attractive business case for next phase	▪ Scaled nationwide HRS network to enable FCEV mass take-up ▪ Profitable, high-growth business

IPHE Background

- IPHE was founded in 2003 to foster international cooperation on hydrogen and fuel cell R&D, common codes and standards and infrastructure development
- 17 member countries plus the European Commission
- IPHE provides a forum for member Governments to share information and policy experiences with the goal of integrating hydrogen and fuel cell (H2FC) technologies into the future energy portfolios
- Member have substantial, long-term resource commitments to H2FC technology research and development activities as well as policies and strategies that effectively advance private sector development of a hydrogen economy
- IPHE members collectively account for over 85% of global GDP, over 75% of the global electricity, and more than 65% of global greenhouse gas emissions

IPHE members: Australia, Brazil, China, European Commission, France, Germany, Iceland, India, Italy, Japan, Republic of Korea, Republic of South Africa, New Zealand, Norway, Russian Federation, United Kingdom, United States

Activities and Priorities

Current IPHE Activities

- Workshop Series
  - Infrastructure
  - Governmental Programs on Emobility
  - Demonstration
  - Stationary Applications
  - Hydrogen as Large Scale Energy Storage
- Virtual University and Global Student Competition
- HFC Global Commercialization & Development Update
- Working Paper on Global Policy Update

IPHE Priorities

- Accelerating market penetration and early adoption of hydrogen and fuel cell technologies and their supporting infrastructure
- Policy and regulatory actions to support widespread deployment
- Raising the profile with policy-makers and public
- Monitoring technology developments

For more information, see http://www.iphe.net

Thank you very much!

Dr. Klaus Bonhoff
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