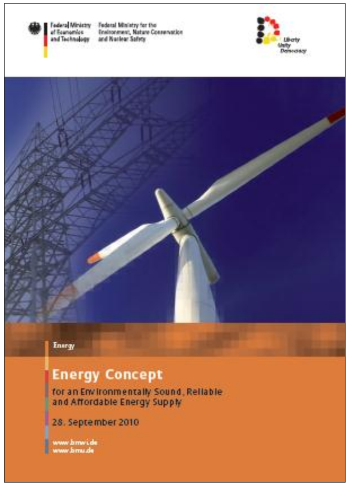
Perspectives for Renewable Energies in Road Transport

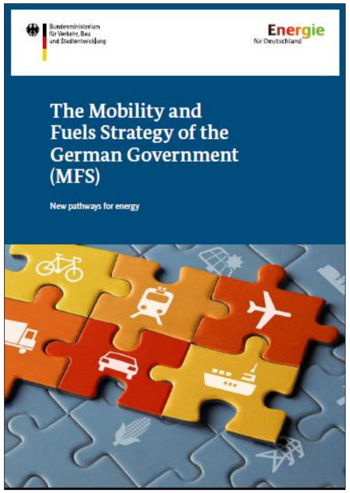
Dr. Klaus Bonhoff | Managing Director (Chair)
NOW GmbH National Organization Hydrogen and Fuel Cell Technology

IEA Working Party on Renewable Energy Technologies (REWP)
Workshop on Renewables and Energy Systems Integration

Denver, West Marriott, USA
September 8-9, 2014

Policy Goals in Germany for Renewable Energies in Energy System and Road Transport





Energy Concept (2010)

reduce <u>overall</u> GHG emissions (vs. 1990):
40% by 2020 ➔ 80%-95% by 2050

increase share of renewables in final energy consumption:
18% by 2020 ➔ 60% by 2050

reduce primary energy consumption:
20% by 2020 ➔ 50% by 2050

reduce final energy consumption of <u>transport</u> (vs. 2005):
10% by 2020 ➔ 40% by 2050

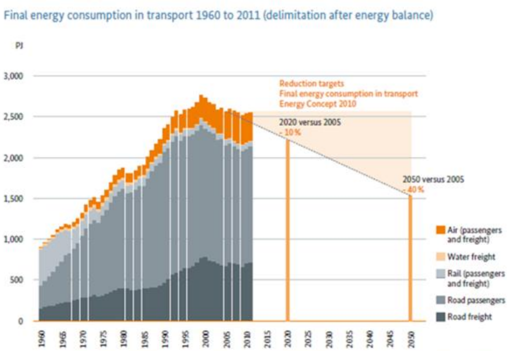


Figure 3: The diagram shows the energy consumption of the individual modes of transport, the current situation and the targets for 2020 and 2050. (Source: own diagram BMVBS / ifeu)

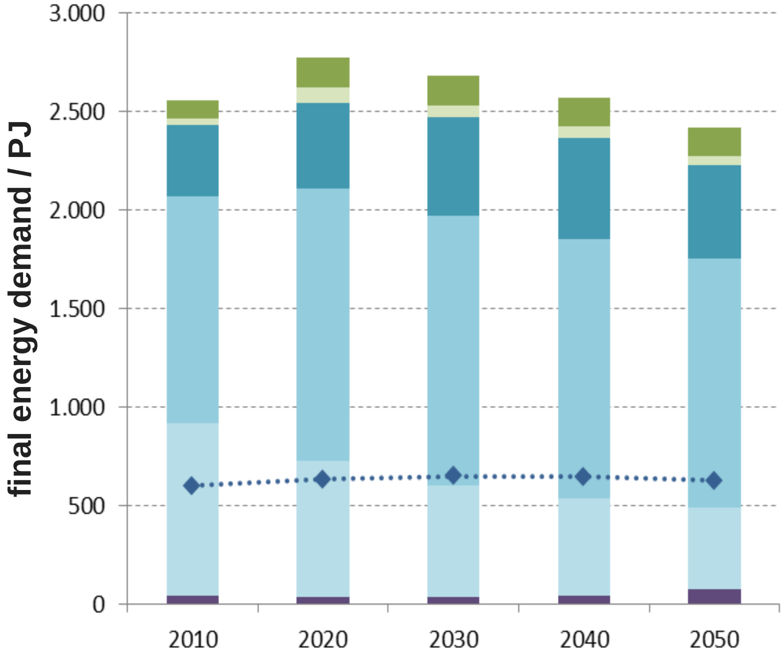
Mobility and Fuels Strategy (2013)

➔ **electrification of drive train (FCEVs, BEVs) needed**

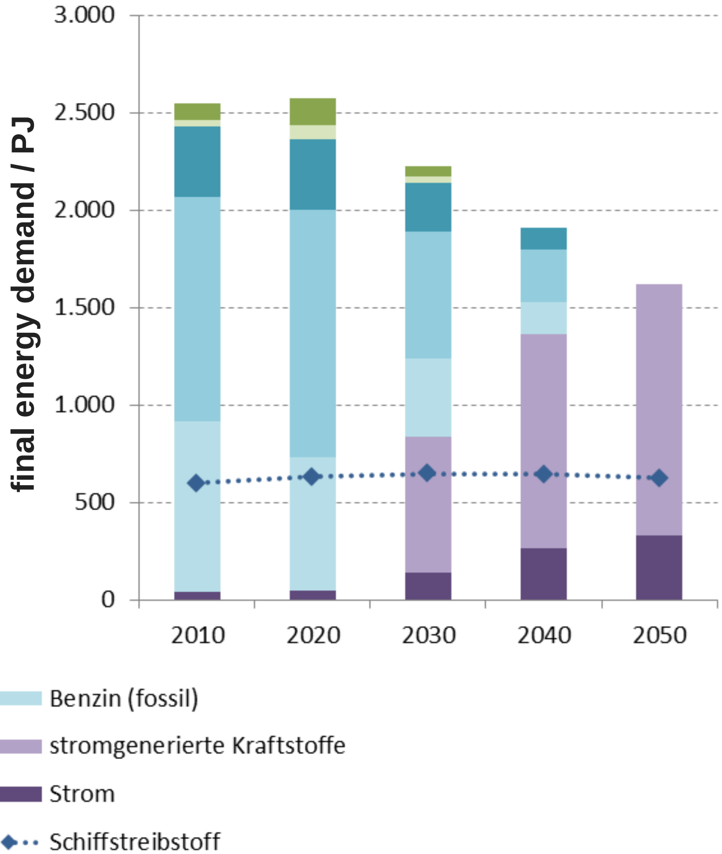
➔ **integration of renewables crucial**

Scenarios for Final Energy Demand in Transportation in Germany

BAU-scenario:
'what happens if you do nothing?'



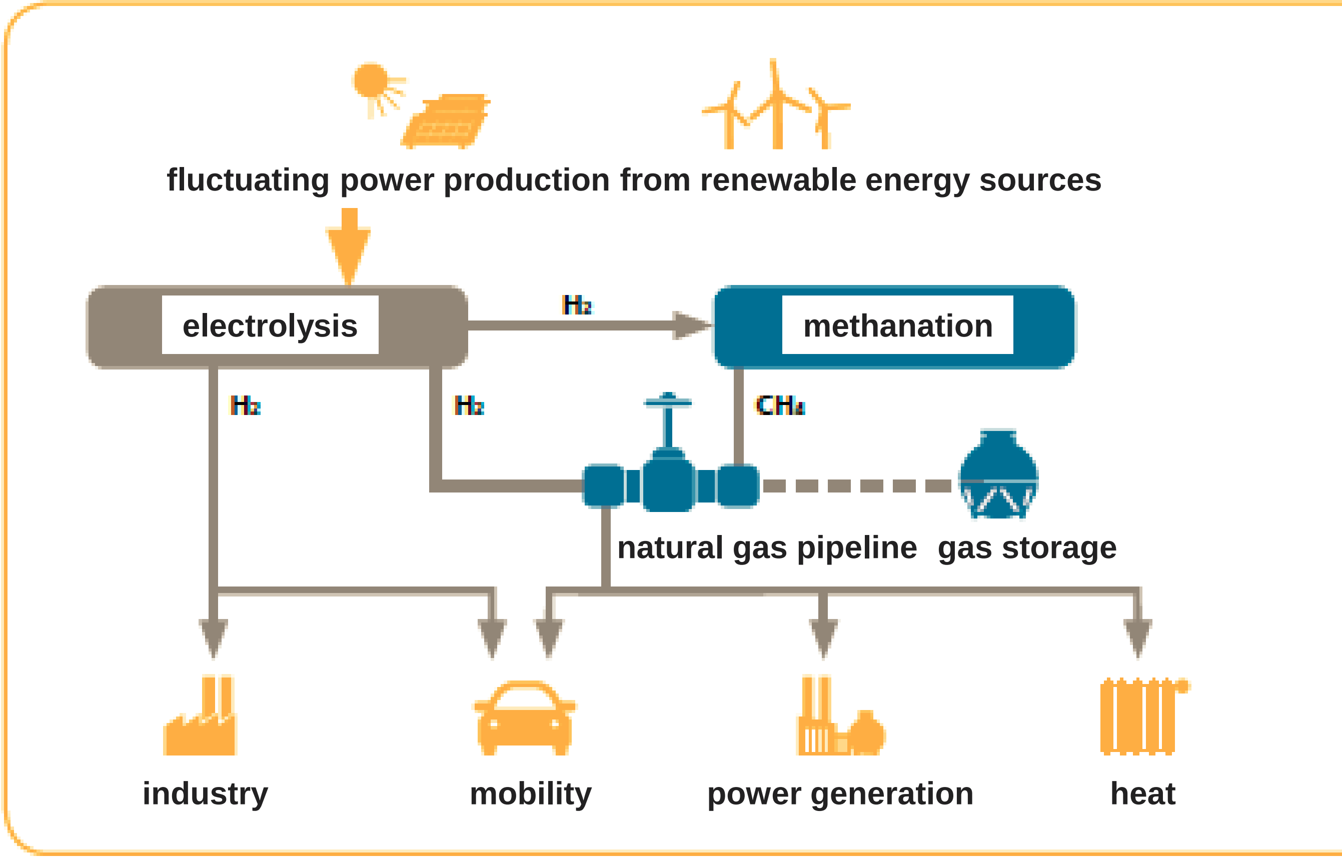
alternative electricity scenario:
'what is possible?'



Power-to-Gas

Production of hydrogen from renewable power sources

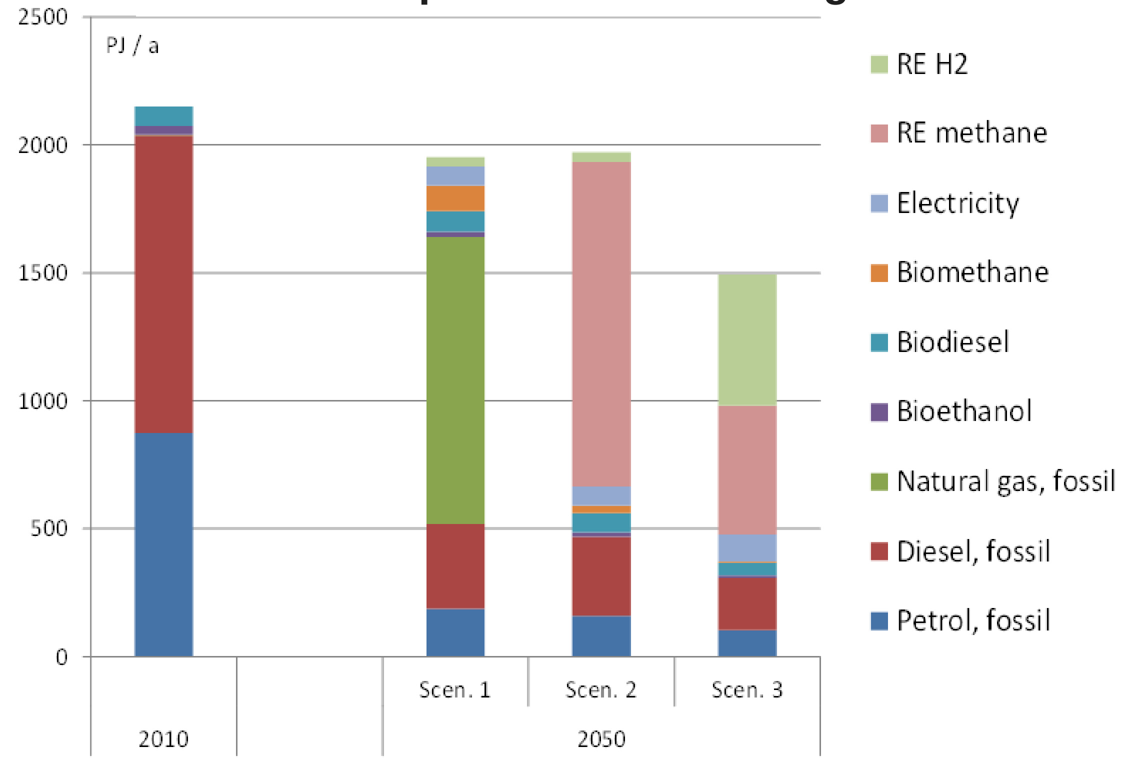
- Optimizing the deployment of fluctuating renewable energy sources
- Allowing an increasing share of renewable power
- Linking the energy sectors



Power-to-Gas Technologies are needed to Reduce Primary Energy Demand in Transportation

Scenarios:
1. high market penetration with methane-operated internal combustion engines, but no PtG;
2. high market penetration with methane-operated internal combustion engines, fuel demand entirely covered with PtG; and
3. considerable shares of both methane-operated internal combustion engines and fuel cell electric engines, fuel demand entirely covered with PtG.

Final energy consumption in road transport and inland navigation



Source:
Power-to-Gas (PtG) in transport
Status quo and perspectives for development
Study in the context of the scientific supervision, support and guidance of the BMVBS in the sectors Transport and Mobility with a specific focus on fuels and propulsion technologies, as well as energy and climate , 2014

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ifeu
ludwig bölkow systemtechnik
DBFZ

Substantial reduction of GHG-Emissions in transportation are only achievable with Power-to-Gas including electrification of the drive-train (Batteries and Fuel Cells)

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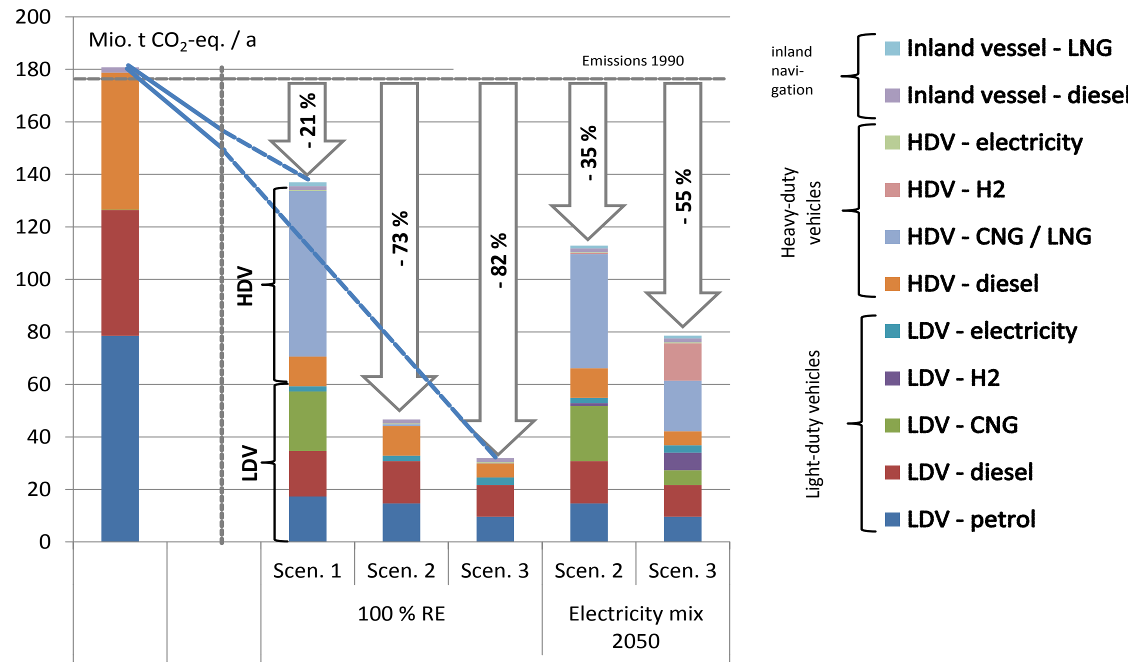
GHG emissions in road transport and inland navigation



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The Overall Power Demand Increases with Power-to-Gas Fuel-Options for the Transportation Sector

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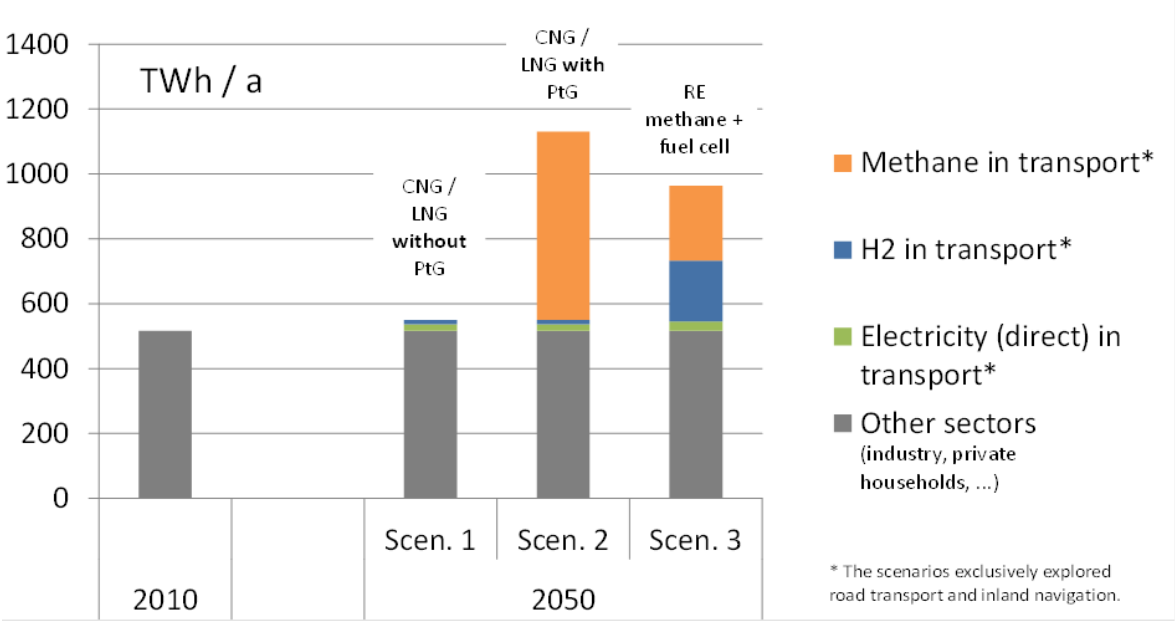
Electricity demand in the scenarios 1–3
(for the demand of the other sectors, the current electricity demand was extrapolated to 2050)



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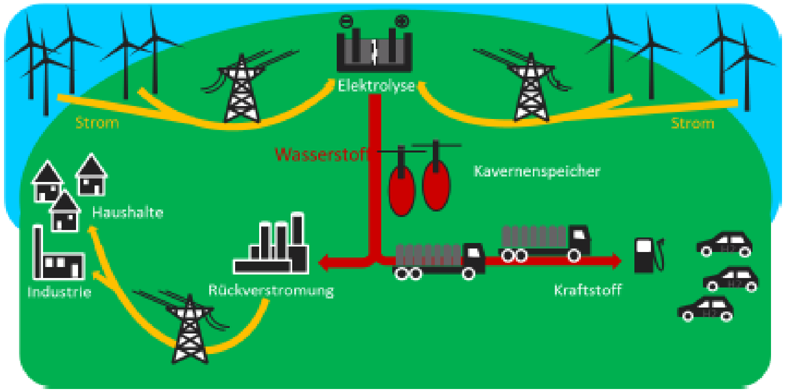
Renewable Electricity for Transportation

economic business cases are feasible

'Integration of Wind-Hydrogen-Systems in the Energy System' – Study Findings Presented 28th January 2013



Questions:

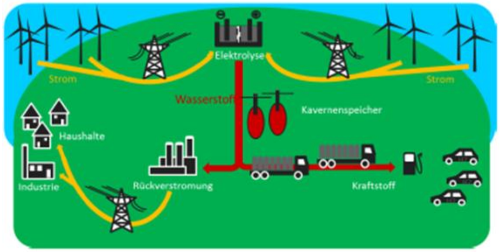
- Volume 'excess' wind power in Germany up to 2030?
- Technology and costs of wind-hydrogen-systems?
- Best options for H_2 transport and stationary use?

Answers:

- Large volumes of 'excess' wind power in Germany's coastal regions expected
- Wind-hydrogen-systems are technologically feasible; limited further R&D required
- Wind-H_2 can be sold as transport fuel with profit in several scenario cases
- Re-electrification of H_2 and sale to stationary sector only in few cases profitable
- Synergies between transport and stationary exist and improve overall profitability

Sensitivities for Hydrogen Production via Electrolysis

Case	"Less fuel"	"Standard Northeast"	Investment electrolysis 700 €/kW	Investment electrolysis 500 €/kW	Price driven electrolysis operation
Electrolysis full load hrs	3.052	3.052	3.052	3.052	5.600
Tonnes H_2 per year	32.044	32.044	32.044	32.044	59.100
Share for power plant	38%	7%	7%	7%	39%
	Specifc Revenue to break even [€/kg H_2 fuel]				
Spot market price	3,71	2,92	2,50	2,08	2,06
40 €/MWh	6,80	5,00	4,58	4,16	
80 €/MWh	9,90	7,08	6,66	6,24	



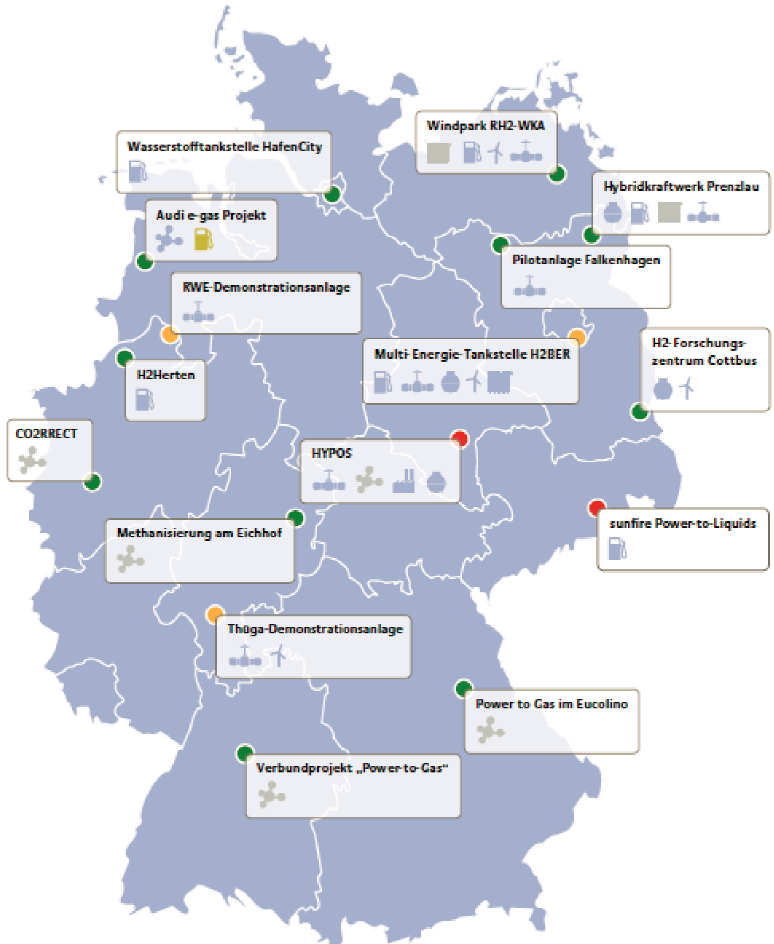
Source:
Study: Integration of Wind-Hydrogen-Systems in the Energy System (2013)

- wind-hydrogen competitive at fuel market
- wind-hydrogen cheaper than hydrogen from natural gas
- wind-hydrogen not competitive

Hydrogen Production from Renewable Energies

stabilizing the grid in the power sector and providing a renewable fuel to the transportation sector

Power-to-Gas
Demonstration Projects in Germany



source: www.powertogas.info; status 12/2013

Wind Hydrogen Project RH2-WKA

Renewable Hydrogen- Werder/Kessin/Altentreptow

Demonstration of Wind-H_2- System
- conception, construction and operation
- electricity supply for wind power plants at times of calm


plant design


ground-breaking ceremony July 2011


start of trial H_2-production December 2012

Project „Power-to-Gas for Hamburg"


- 1MW PEM-electrolyzer
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ground-breaking ceremony June 2013

e.on HYDROGENICS SolviCore Deutsches Zentrum für Luft- und Raumfahrt Fraunhofer

Wind-Hydrogen-System at the Energy Park in Mainz

ENERGIESPEICHER

- Project consortium: Stadtwerke Mainz, Siemens, Linde, Hochschule Rhein-Main
- 2 MW PEM electrolyzer
- Large scale ionic compressor
- Multiple uses of hydrogen
- Planned start of operation in 2015

Battery Electric Vehicles (BEV)

Commercial offers (07/2014)

Charging Infrastructure in Germnay

MR Hamburg
MR 1.0, MR 2.0

MR Bremen / Oldenburg
MR 1.0, MR 2.0

MR Berlin
MR 1.0, MR 2.0, SF

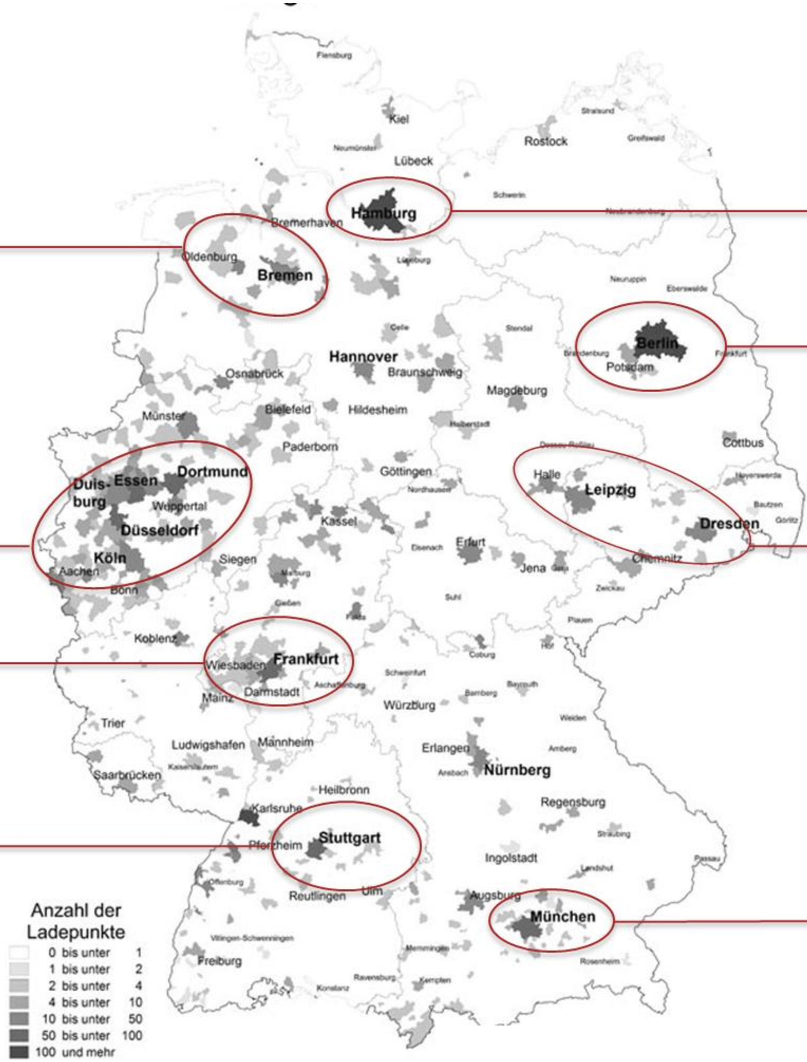
MR Rhein-Ruhr
MR 1.0, MR 2.0

MR Sachsen
MR 1.0, MR 2.0, SF

MR Rhein-Main
MR 1.0, MR 2.0

MR Stuttgart
MR 1.0, MR 2.0, SF

MR München
MR 1.0, SF



Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

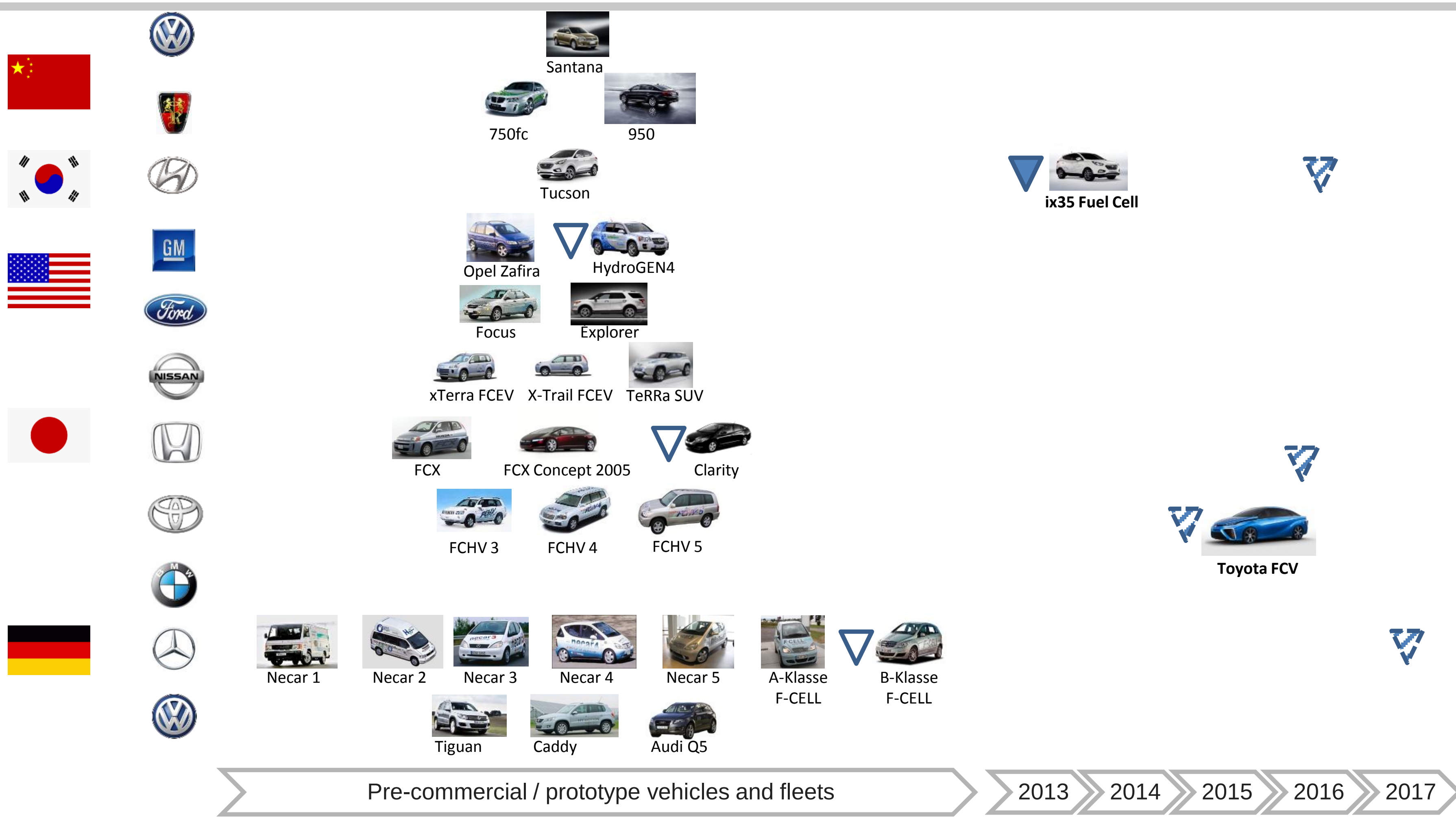
Developing Charging Infrastructure

Multiple charging options

Fuel Cell Vehicles (cars and busses) and Hydrogen Stations

Fuel Cell Vehicles (FCV)

series production vehicles
commercial introduction
commercial introduction announced



50-Hydrogen-Station Program in Germany

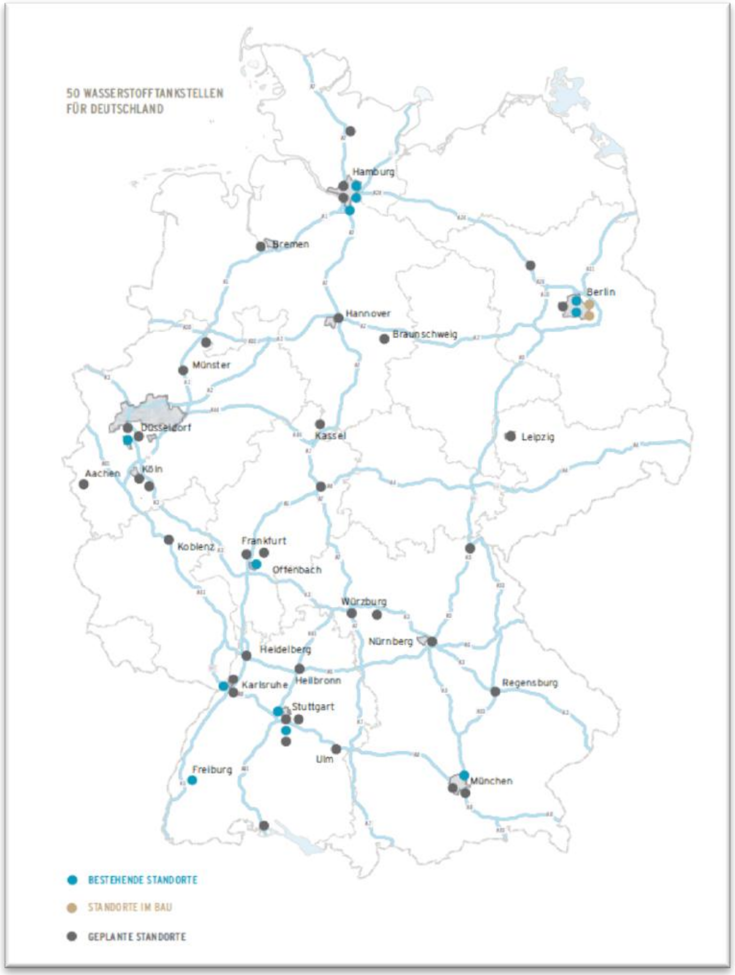
field testing of technical innovations and
connecting corridors between metropolitan regions

- **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 Program for Hydrogen and Fuel Cell Technology (NIP)
  - overall investment more than €40 million (US$51 million)
- **coordination by NOW GmbH in the frame of the Clean Energy Partnership (CEP)**

Federal Ministry of Transport, Building and Urban Development

Clean Energy Partnership
CEP

Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie
nip



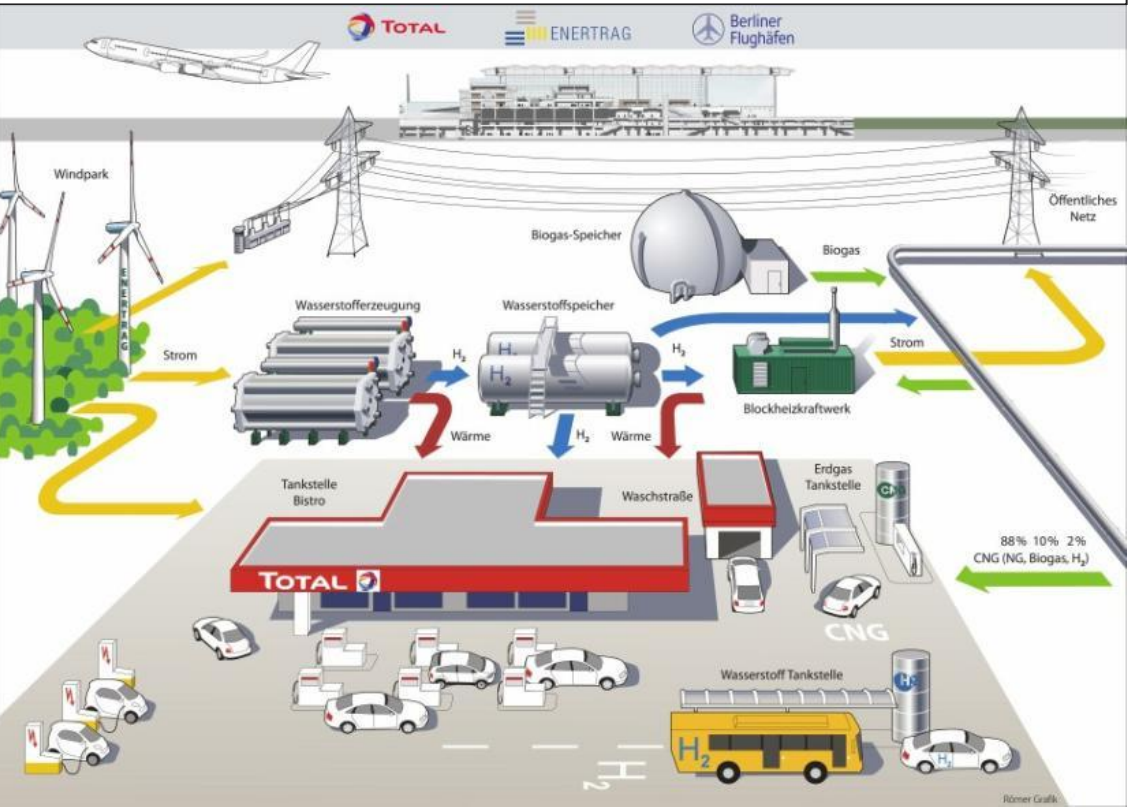
Current Status:

- location planning of the 50 HRS has been finalized
- 15 HRS in operation, application for funding for 23 HRS, 12 HRS are in the planning phase
- the majority of the HRS will be operated by H2-Mobility after the funded project time frame has ended
- ~110 FCEV's are currently on the road

Hydrogen Station Deployment
demonstrating Wind-Hydrogen for transportation

Clean Energy Partnership CEP
Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie
nip

hydrogen as part of an integrated energy system



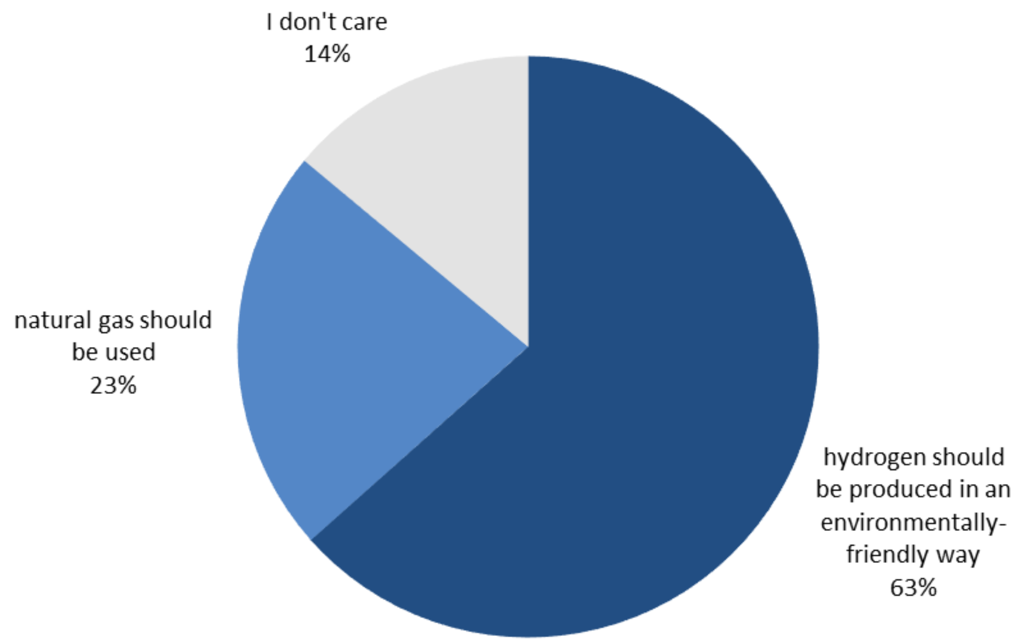
Total: multi-energy fuelling station

refueling renewable power

Total Refueling Station at Berlin-Schoenefeld
Opening on May 23th, 2014

Production of hydrogen

Hydrogen can be produced in an environmentally friendly way from renewable energies. This is still very expensive. It would be cheaper to produce hydrogen from natural gas. Do you think that natural gas should be used as a temporary solution, or should hydrogen be produced environmentally friendly even with a higher price?



(Survey 01/2013, n=1012)

Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Gefördert durch:

Bundesministerium für Verkehr, Bau und Stadtentwicklung

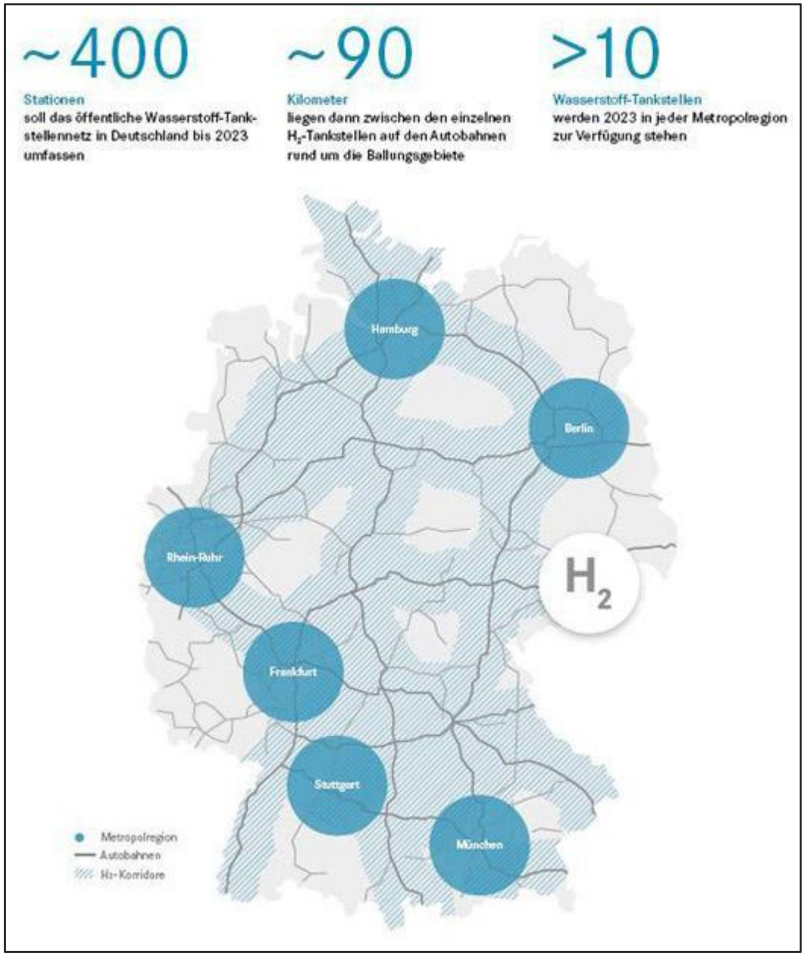
H2-Mobility action plan until 2023

Air Liquide, Daimler, Linde, OMV, Shell and Total agree on an action plan for the construction of a hydrogen refueling network in Germany.

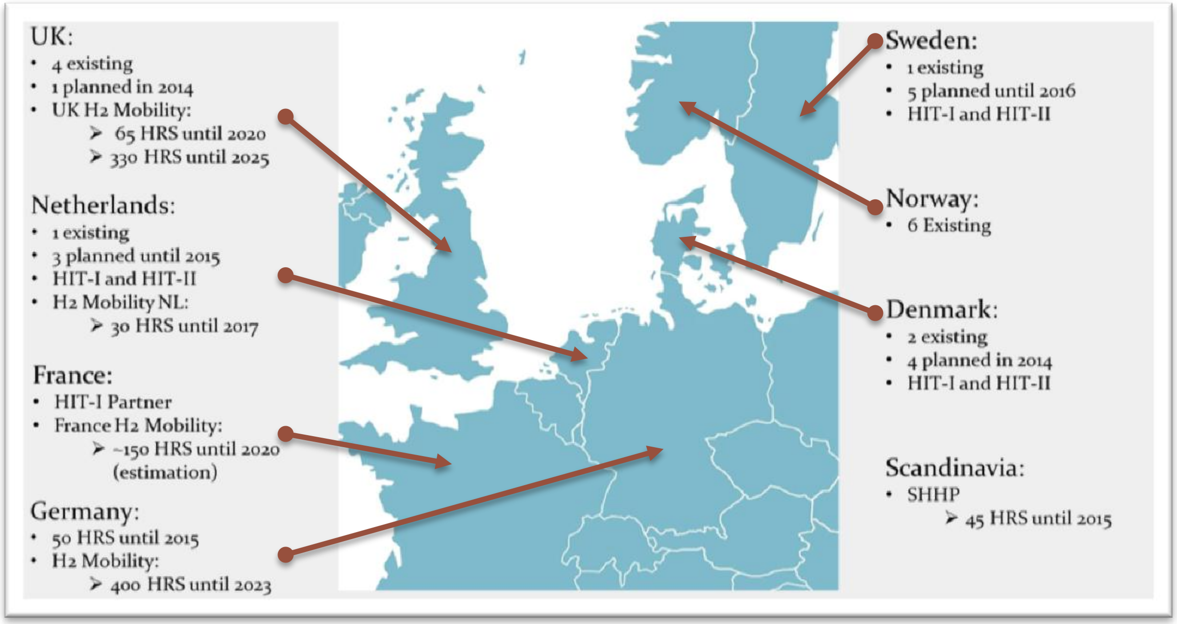
Targets:

- **400 HRS** until **2023** (100 HRS until 2017).
- **350 mio. €** investment.
- Max**. 90 km** distance between two HRS at the motorway.
- **10 HRS** in each metropolitan area.

H2 Mobility



Development of an Aligned European Hydrogen-Infrastructure Strategy



- Several HRS initiatives and roll-out scenarios throughout Europe are currently in place
- Strong coordination within Europe is needed since:
  - the initiatives are at different development phases
  - there are only limited funding budgets available
  - an aligned strategy increases the political awareness

Clean Power for Transport Directive General

Targets of the directive:

- Solve the "Chicken-and-Egg-Problem" = Energy/Fuel– Powertrain – Infrastructure, Safety for investment into alternative power trains due to availability of infrastructure.
- Establishment of an EU market for alternative fuels (Methane / H2 / Electricity) and power trains.
- Enforcement of innovation and competitiveness of the EU

Key elements of the CPT-directive:

- Member states (MS) have to develop national implementation plans (NIP); no specific guidelines for infrastructure by the directive: MS have to decide within their NIP about the „appropriate number“ for „Charging/H2/LNG&CNG“-infrastructures
- Establishment of binding technical standards and specifications for the interconnection between „Fuel / Vehicle / Infrastructure“. Motivation/Target: Interoperability und anti-discriminatory availability of infrastructure.

Effects for HRS and FCEV'S:

- Integration of the directive into national laws: 24 month after empowerment (expected: mid of 2014)
- H2-Infrastructure: 31.12.2025 (just for MS which will use the H2 option)
- Relevant Standards:
  - The hydrogen purity dispensed by hydrogen refuelling points shall comply with the technical specifications included in the ISO 14687-2 standard.
  - Hydrogen refuelling points shall employ fuelling algorithms and equipment complying with the ISO/TS 20100 Gaseous Hydrogen Fuelling specification.
  - Connectors for motor vehicles for the refuelling of gaseous hydrogen shall comply with the ISO 17268 gaseous hydrogen motor vehicle refuelling connection devices standard.
- Transition period for all fuel options: 36 month after empowerment of the directive all new or renewed fuel infrastructure has to follwed the mentioned standards.

Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Thank you very much!

Dr. Klaus Bonhoff

Managing Director (Chair)

NOW GmbH
National Organization Hydrogen and Fuel Cell Technology

Fasanenstrasse 5, 10623 Berlin, Germany

download: www.now-gmbh.de

Back-up

Final Energy Consumption of the Transport Sector in Germany

Final energy consumption in transport 1960 to 2011 (delimitation after energy balance)

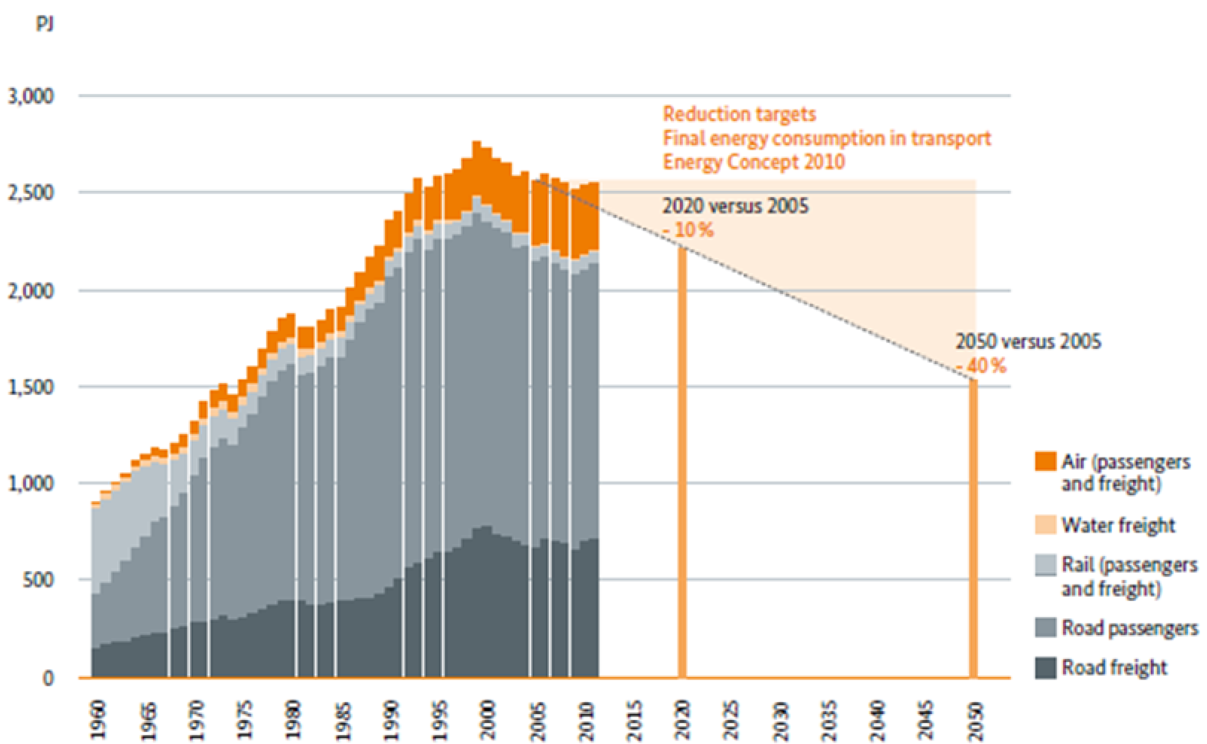


Figure 3: The diagram shows the energy consumption of the individual modes of transport, the current situation and the targets for 2020 and 2050. (Source: own diagram BMVBS / ifeu)

Well-to-Wheel Analysis for Selected Drive Train Technologies and Energy Sources

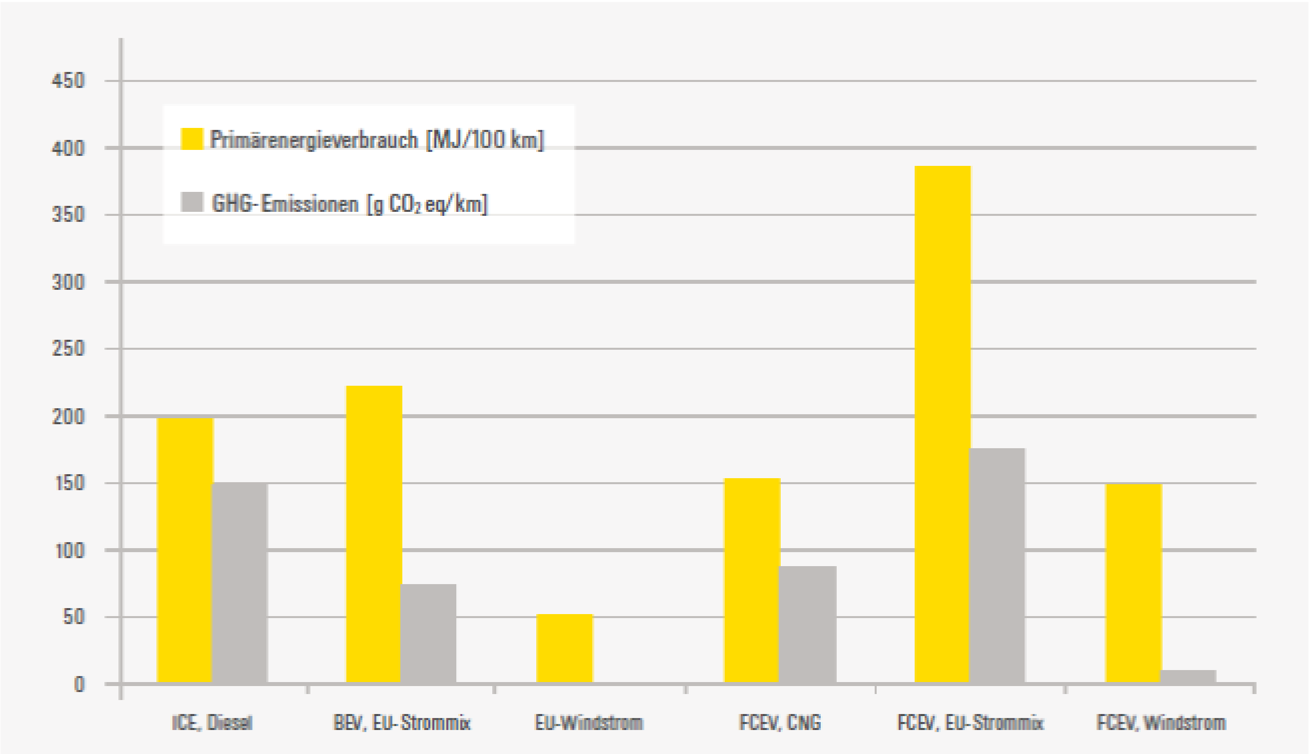


Abbildung 1: Primärenergieverbrauch und Greenhouse-Gas-Emissionen ausgewählter Antriebskonzepte gemäß einer Well-To-Wheel-Analyse nach [3]

source:
R. Edwards, J.-F. L., J-C. Beziat (2011):
„Well-to-wheels Analysis of Future Automotive Fuels and Powertrains in the European Context Version 3c“,
JEC – Joint Research Centre-EUCAR-CONCAWE collaboration, Luxemburg

Wind Hydrogen Project RH2 -WKA

Renewable Hydrogen- Werder/Kessin/Altentreptow

WIND-projekt

WiWa

Demonstration of Wind-H_2- System

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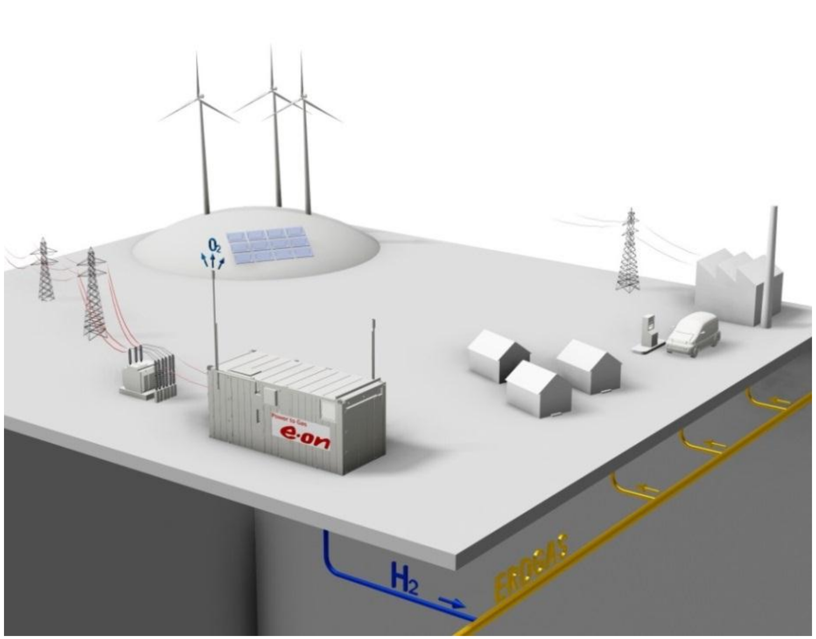

- 1MW PEM-electrolyzer
- injection of H_2 into natural gas grid

ground-breaking ceremony June 2013

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Wind-Hydrogen-System at the Energy Park in Mainz

ENERGIESPEICHER
Forschungsinitiative der Bundesregierung

Projektträger für das
Bundesministerium für Wirtschaft und Energie

- Project consortium: Stadtwerke Mainz, Siemens, Linde, Hochschule Rhein-Main
- 2 MW PEM electrolyzer
- Large scale ionic compressor
- Multiple uses of hydrogen
- Planned start of operation in 2015