GermanHy

GermanHy
A Study Addressing the Question: 'Where Will the Hydrogen in Germany Come from by 2050?'

Financed by the
German Federal Ministry of Transport, Building and Urban Affairs (BMVBS)

in Collaboration with the
German National Organization Hydrogen and Fuel Cell Technology (NOW)

Summary of Results

June 26, 2008

Overview

1. Targets for Road Transport Sector in Germany
2. Questions and Rationale of GermanHy
3. Study Scenarios and Assumptions
4. Relevance of Hydrogen in Road Transport
5. Sources for Hydrogen in Germany
6. Development of a Hydrogen-Infrastructure

7a. Costs of Hydrogen

7b. Reduction of CO_2 and other Emissions

7c. Energy-Imports and Renewable Energies

8. Role of Hydrogen as a Transport Fuel
9. Summary of Main Results

1. Targets for Road Transport Sector in Germany

targets for tomorrow's mobility

- reduction of transport emissions
- decrease oil dependency
- increase energy efficiency
- enhance share of renewable energies
- strengthen competitiveness of German automotive industry

why hydrogen?

- hydrogen (H_2) is a carbon-free energy carrier
- hydrogen can be generated from different primary energy sources
- H_2 facilitates the use of the highly efficient fuel cell (FC)
- hydrogen may serve as storage media for renewable energies
- H_2 and FC are key technologies with a high potential for value creation

fuel strategy of federal government: **hydrogen can play an important role as a transport fuel in the future**

2. Questions and Rationale of GermanHy

key questions regarding the introduction of hydrogen in the transport sector

- which share of future fuel demand may hydrogen take over in Germany?
- which energy sources may hydrogen, satisfying a growing demand, be economically produced from (time horizon 2020, 2030, perspective 2050)?
- how can hydrogen be distributed from the place of production to the end user?
- what effects does the use of hydrogen in transport have on mobility costs, emissions, share of renewable energies and dependency on energy imports ?

rationale of GermanHy

- GermanHy provides NOW with information for decision-making regarding the implementation of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) in the realm of hydrogen infrastructure (R&D-needs, demonstration projects)
- GermanHy focuses on the introduction of hydrogen as an alternative transport fuel, defining both potentials and limitations of hydrogen in the overall energy system. detailed examination of other alternative propulsion concepts is not part of the study

GermanHy

3. Study Scenarios and Assumptions

3 scenarios were modelled:

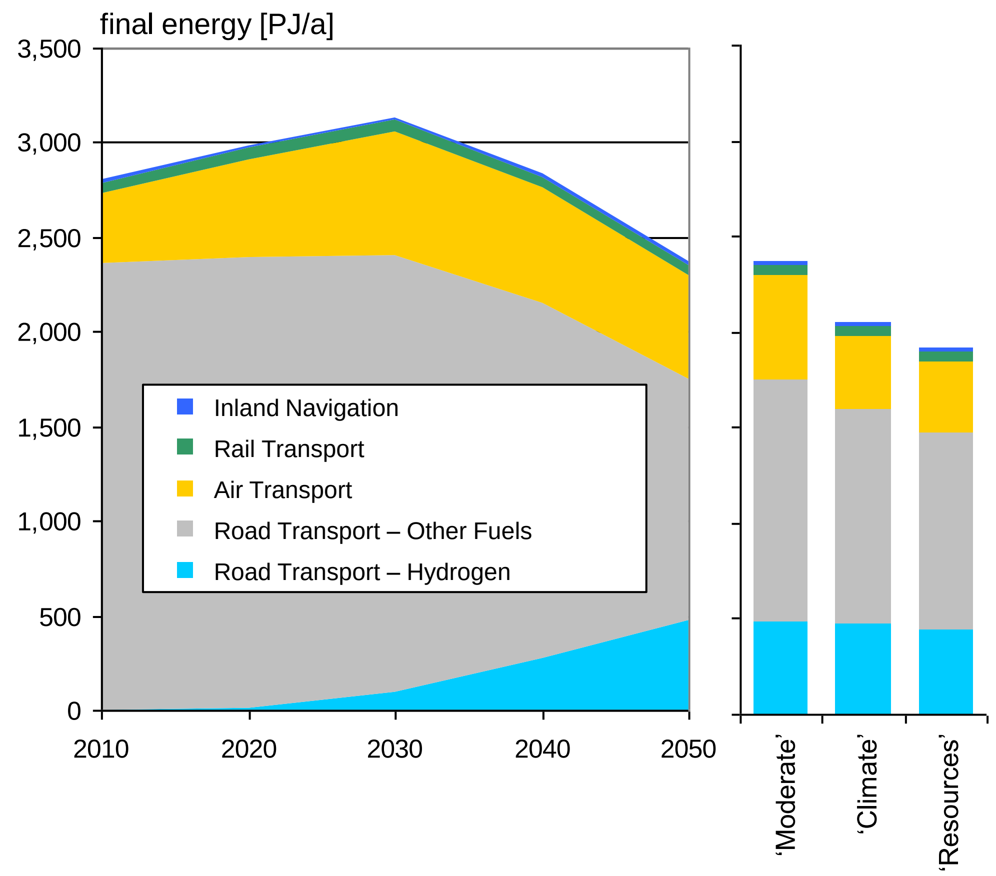
	1 Moderate Development	2 Climate Protection	3 Shortage of Resources
motivation	conservative trend progression	ambitious climate protection policies	massive shortage of fossil resources
energy price (crude oil)	54 $/bbl in 2020 111 $/bbl in 2050	54 $/bbl in 2020 111 $/bbl in 2050	248 $/bbl in 2020 202 $/bbl in 2050
climate gas reduction targets	-20% by 2020 -40% by 2050	-40% by 2020 -80% by 2050	-20% by 2020 -40% by 2050
additional costs of fuel-cell vehicles	reduction of costs for fuel-cell passenger/light duty vehicles to level of modern diesel vehicles		
renewable energies	minimum of 20% share in primary energy consumption by 2020		

- central assumptions of GermanHy based on *BMWi Energiereport 2005* and *BMU Leitstudie 2007*
- approach: cost-optimizing models, political assumptions, inclusion of stakeholders

4. Relevance of Hydrogen in Road Transport

- Germany uses some 30% of its primary energy in the transport sector
- hydrogen and fuel cells can assume great importance in road transport by 2050, and evolve into central components of a more diversified market of fuels and propulsion concepts
- over 70% of all cars and LDVs may run on hydrogen and fuel-cell technology in 2050
- this equates to a hydrogen-share of 20 to 25% in the overall transport energy demand, depending on the scenario applied
- key limiting factor is the market penetration achieved by hydrogen vehicles

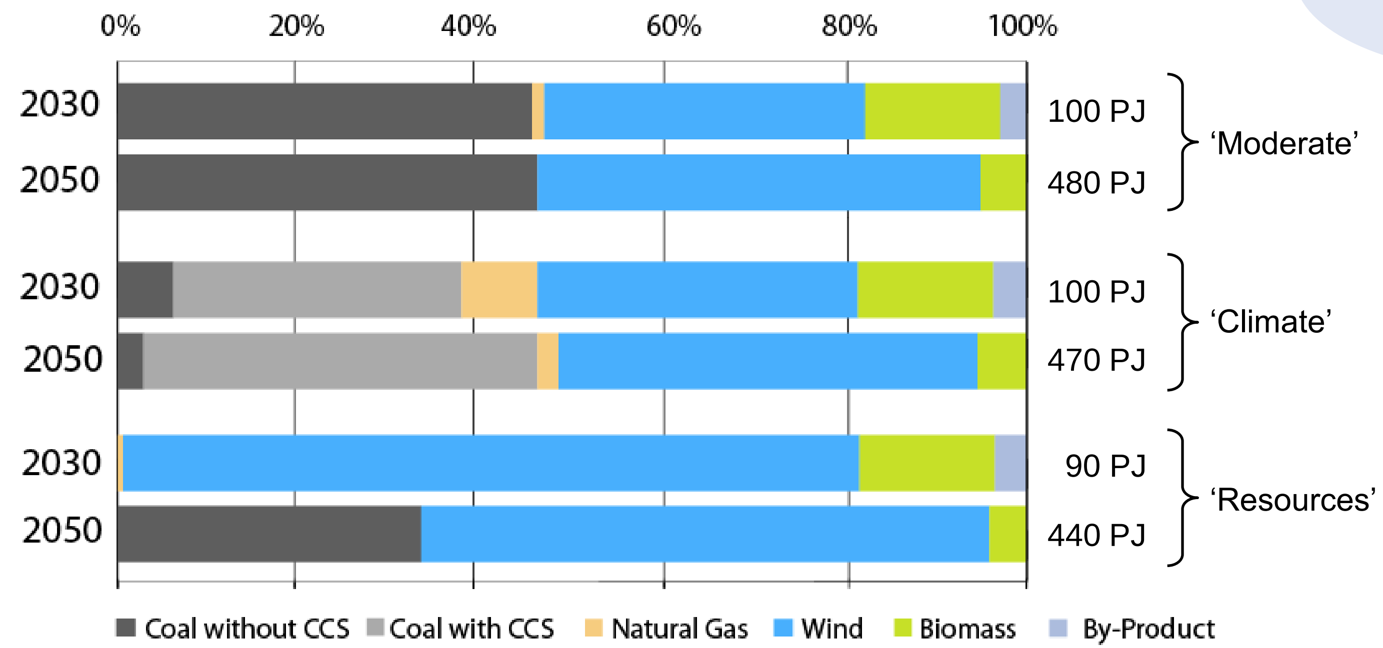
shares of transport modes in final energy consumption



5. Sources for Hydrogen in Germany (I/II)

political imperative:
share of renewable energies
at least 50%

shares of primary energy carriers in hydrogen production



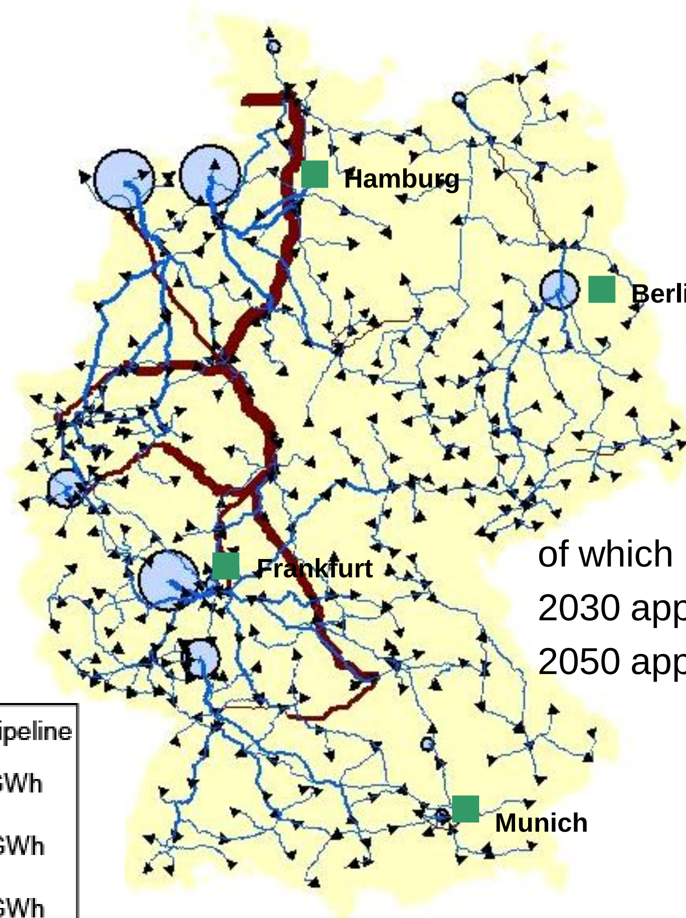
- hydrogen will be produced from different primary energy sources. depending on the scenario applied, the respective share of individual sources varies
- the future mix of energies used for hydrogen production will depend on political targets and framework conditions, as well as achievements on technological development

5. Sources for Hydrogen in Germany (II/ II)

biomass	**biomass** gasification represents the most economical option for producing hydrogen from renewable energies, but the potential of biomass is limited
wind	**wind** is the most important renewable resource for hydrogen generation, and will further substantially gain in significance with growing shortage of fossil resources
	therefore, central **electrolysers** will play a key role in converting renewable energies to hydrogen
imports	with high rates of market penetration, **imports** - mainly electricity and hydrogen from renewable energies - may markedly grow in importance
by-product	most **by-product** hydrogen is already being used, though some potential remains
black coal lignite	as of 2020 gasification of black **coal** and lignite may represent an economical option, but CO_2 capture and storage (CCS) is mandatory to meet tough climate targets
natural gas	without CCS, more **natural gas r**eformation is needed to meet climate targets
on-site	**on-site** production may play a role in the introductory phase (though there remains some uncertainty about economic viability)

6. Development of a Hydrogen-Infrastructure

- the build-up of infrastructure happens step by step, starting from densely populated/urban areas
- during the introductory phase (until 2030) the transport by trailer of centrally produced liquid hydrogen to filling stations dominates (e.g. to integrate offshore wind and by-product hydrogen)
- with growing demand most hydrogen will be distributed by pipelines in compressed form
- on-site production of hydrogen from natural gas, biomass and electrolysis may play a role regionally



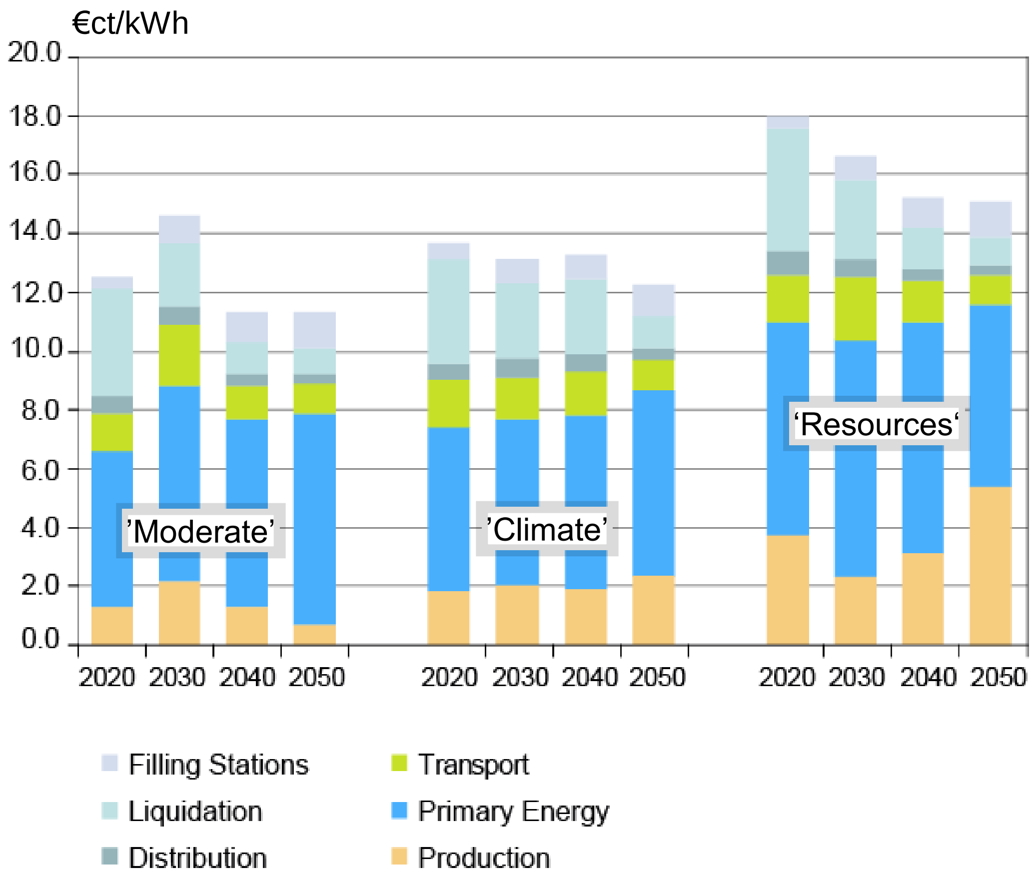
LH_2 Production		H_2 Liquid Transport by Trailer	CH$_2$ Transport by Pipeline
(large circle)	800 - 2400 GWh	800 - 2392 GWh	6641 - 6911 GWh
(medium circle)	248 - 800 GWh	393 - 800 GWh	5947 - 6640 GWh
(small circle)	24 - 248 GWh	<103 - 393 GWh	5 - 2310 GWh

of which pipeline
2030 approx. 20%
2050 approx. 80%

scenario 2030 “Moderate”

GermanHy

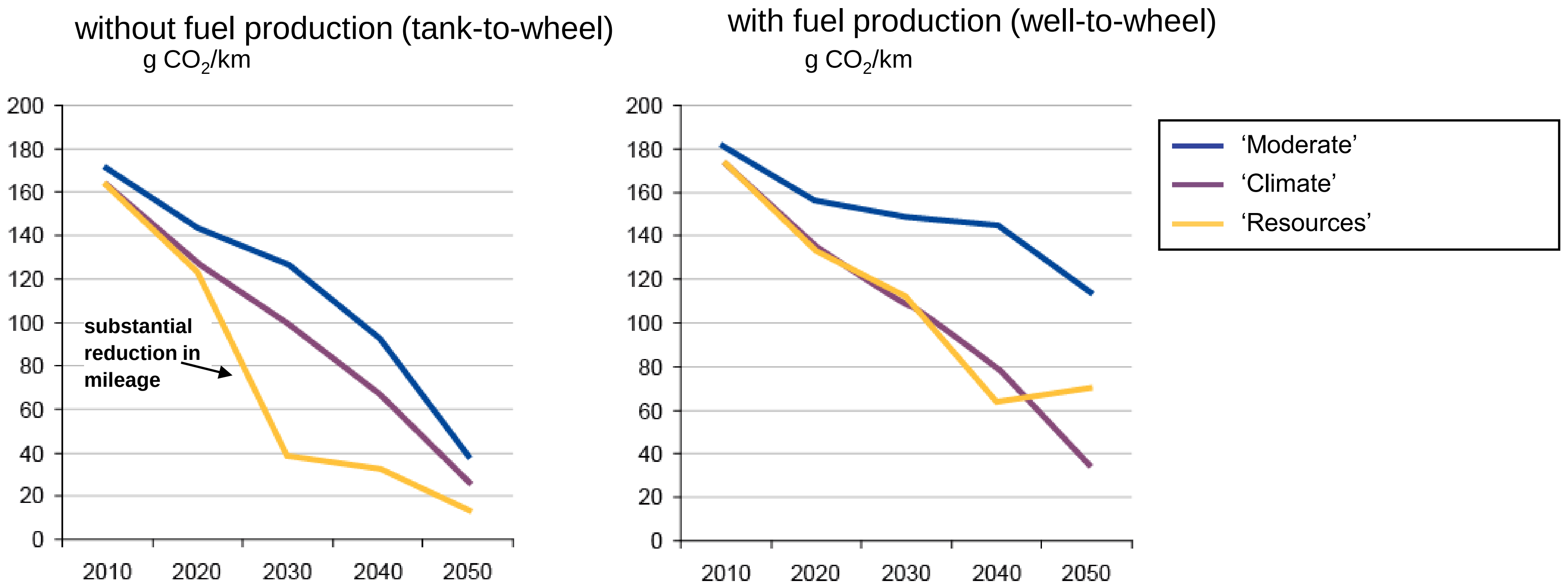
7a. Costs of Hydrogen



- fuel costs of hydrogen are comparable to today's costs of fossil fuels (both before tax)
- 50 to 80% of costs stem from primary energy and hydrogen production
- during the introductory phase higher costs arise from underutilization of infrastructure
- important factors of influence: political targets on climate protection and renewable energies, development of energy prices and viability of CO_2 capture and sequestration

7b. Reduction of CO_2 and other Emissions

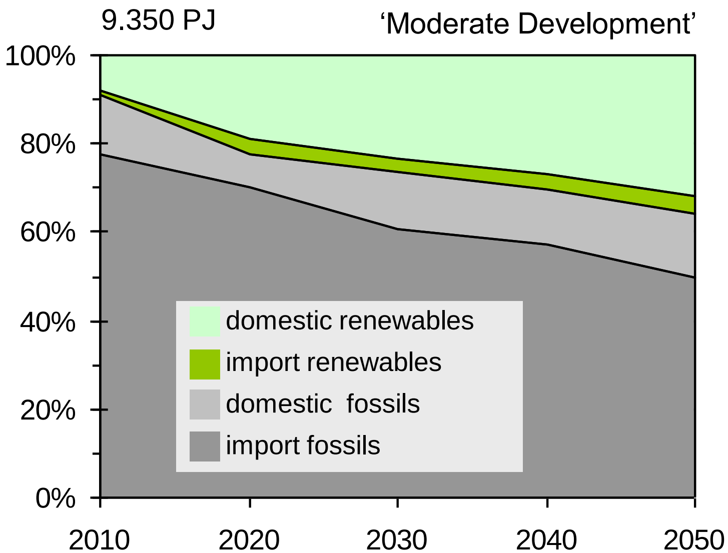
fleet emissions (passenger cars)

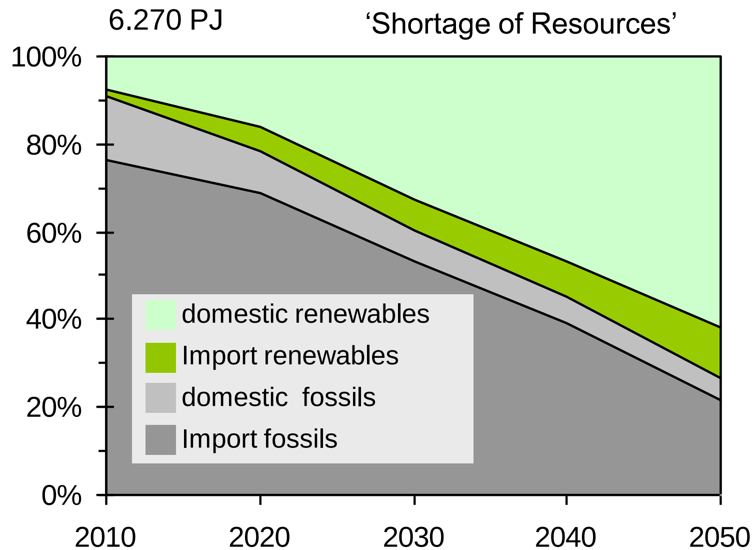


- carbon-dioxide emissions of passenger cars can be substantially reduced with hydrogen (fleet average may be as low as 20 g/km tank-to-wheel, and 36 g/km well-to-wheel emissions, if hydrogen is generated from renewable energies, or fossil energies using CCS)
- hydrogen-driven fuel cell vehicles cause no local air pollutants and only insignificant noise emissions

7c. Energy-Imports and Renewable Energies

primary energy supply in Germany



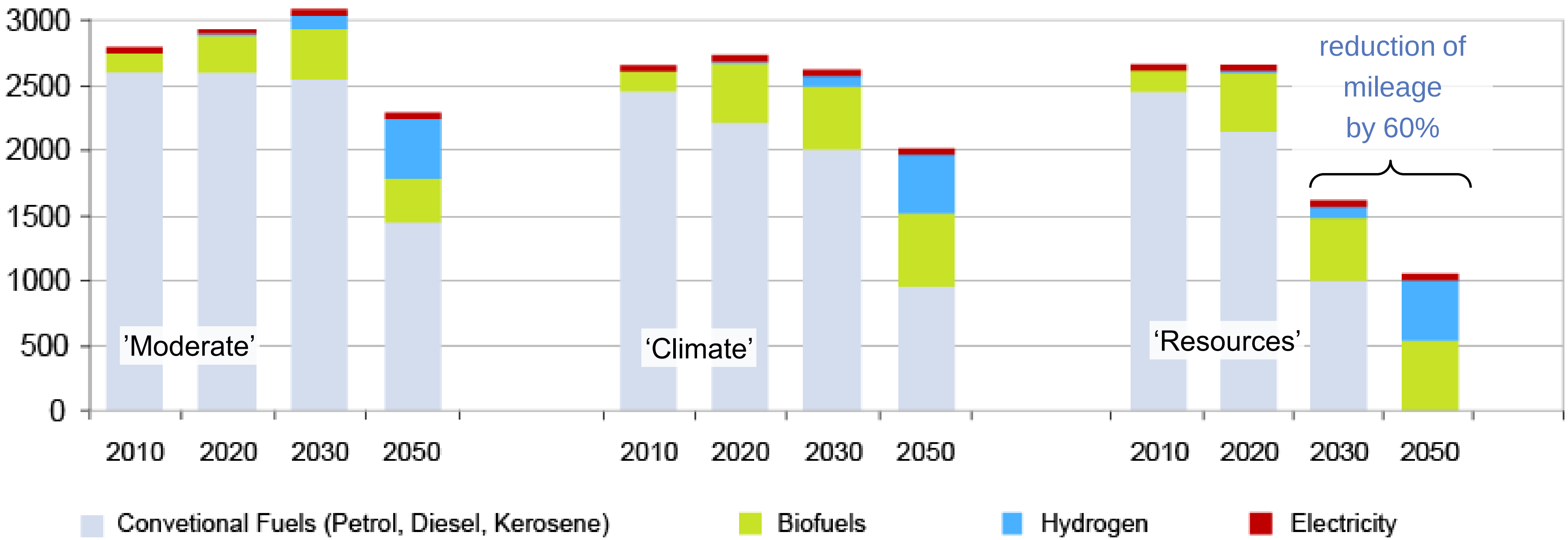


- dependency on energy imports drops from over 90% to 55% or even 35%, depending on scenario
- share of renewable energies rises from 10% to 30% or even 75%

- share of renewables in transport sector rises from below 10% to above 50%
- availability of domestic lignite is reduced drastically in scenario 'Shortage of Resources'

8. Role of Hydrogen as a Transport Fuel

final energy consumption of transport sector PJ/a



challenges:

- energy supply for mobility will be more diversified and complex
- competition of demand for energy will increase, especially for biomass

the role of hydrogen:

- together with other alternative fuels, hydrogen can satisfy over 50% of the demand in 2050
- still, in scenario 'Shortage of Resources' the measures suggested cannot guarantee that present mobility patterns can be maintained

GermanHy

9. Summary of Main Results (I/ IV)

- hydrogen can turn into an important energy carrier in the transport sector by 2050 and cover some 20% of the total transport energy demand
- depending on framework conditions, hydrogen can satisfy the fuel demand of up to 70% of cars / light duty vehicles by 2050, even if a significant shortage of fossil resources materializes
- in case of a drastical decrease in imports of fossil energy, as with scenario ‘Shortage of Resources,’ more renewable energies must be used, larger increases in energy efficiency be achieved, and greater emphasis be placed on energy saving behavior
- hydrogen is generated from a range a primary energies. during the introductory phase, regionally available ‘by-product’ hydrogen from industrial facilities, on-site reformation of natural gas, and gasification of biomass may play a role. in the longer term, coal with CO_2 capture and storage dominates, together with wind energy. there are uncertainties with regard to the availability of CCS and concerning delays during the expansion of renewable energy supply structures
- distribution is dominated by delivery of liquid hydrogen by trailer during the introductory phase, when only small amounts are needed. transport of compressed hydrogen in pipelines takes over after 2030, as soon as growing demand makes it economically feasible. on-site production contributes to satisfying regional hydrogen demand

GermanHy

9. Summary of Main Results (II/IV)

- the growth of hydrogen infrastructure happens successively, starting from densely populated/urban areas. the costs for building up an infrastructure covering the whole of Germany by 2030 amount to less than Euro 1 billion per year
- mobility based on hydrogen and fuel cells will be possible at today's costs, if the development tasks for fuel-cell vehicles are met. after an introductory phase, the costs of hydrogen will amount to between 3 and 4 €ct/km
- hydrogen can cut the direct carbon-dioxide emissions of the transport sector by up to 80%. depending on the particular path of hydrogen production concerned, CO_2 emissions of FC cars can be reduced to between 40 and 20g CO_2/km (in the case of renewable energies and coal with CCS)
- the share of renewable energies in hydrogen production can be raised to above 60% by 2050. still higher shares are possible through greater imports of renewable energies
- a bigger share of renewable energies results in marginally higher cost in scenario 'Moderate Development.' in scenario 'Shortage of Resources,' renewables are competitive
- dependency on energy imports can be reduced from above 90% at present to 50%, or even 30%, depending on scenario
- the introduction of hydrogen and fuel cells will not succeed without political support, but requires conducive framework conditions

GermanHy

9. Summary of Main Results (III/IV)

it can be concluded:

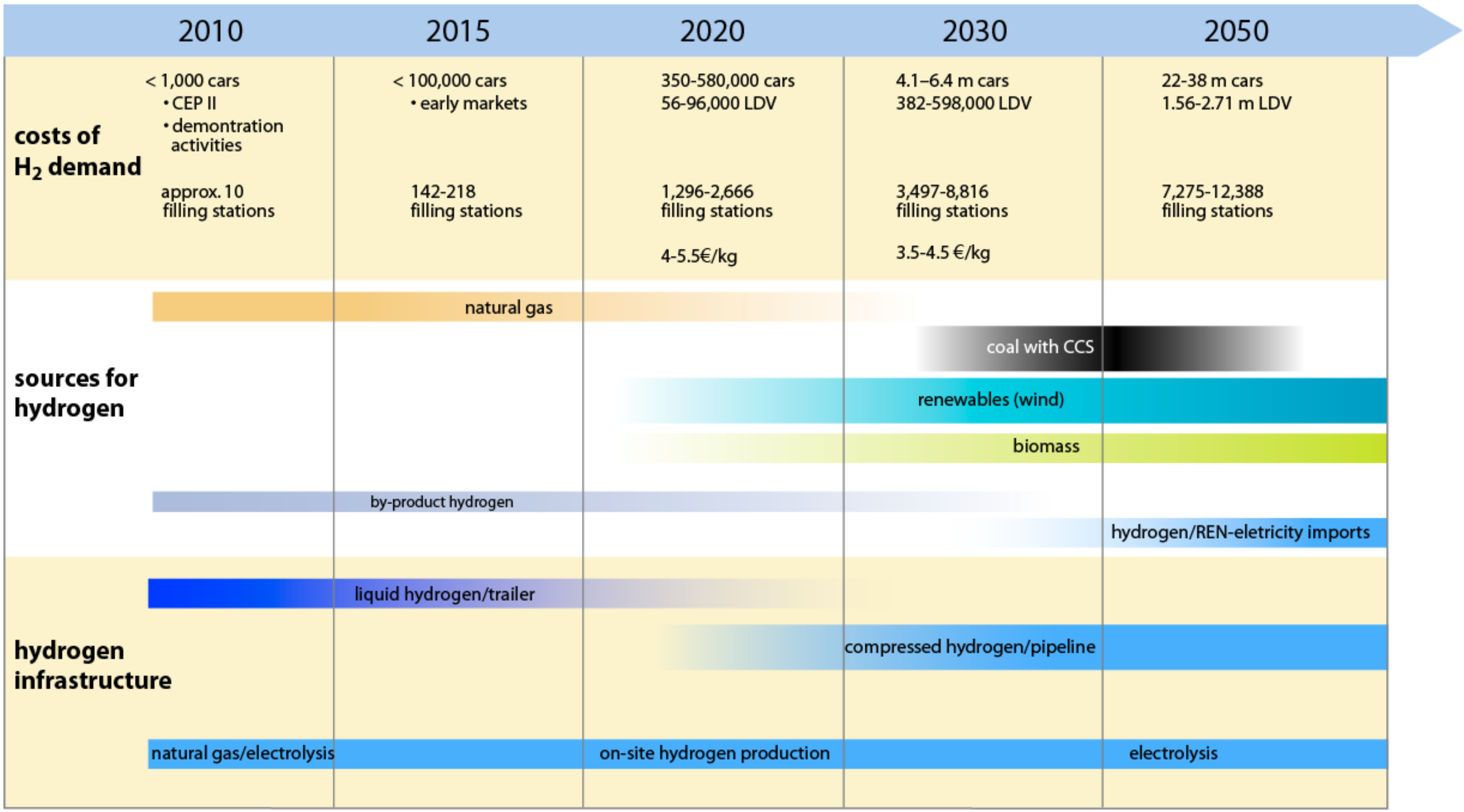
- in scenario **’Moderate Development’** the use of hydrogen is recommendable due to advantages in economics, CO_2 reduction and security of supply
- with scenario **’Climate Protection’** hydrogen is needed to ensure that CO_2 emissions are cut in the transport sector and that more renewable energies are used here
- in scenario **’Shortage of Resources’** reliance on hydrogen is imperative to maintain at least a part of today’s private transport volume in the future

related measures and technologies:

- increases in energy efficiency are required in all scenarios and economic sectors
- batteries are a key technology for future mobility; battery-electric and plug-in-hybrid vehicles are complementary to fuel-cell and hydrogen propulsion technology
- biofuels will play an important role in the transport sector in spite of their limited availability, but mainly be used by heavy duty vehicles, aircraft and ships

GermanHy

9. Main Results (IV/IV) – The GermanHy Roadmap:



Thank you

download of presentations and final report:

www.germanhy.de