Environmental benefits of hydrogen and fuel cells in transport
Europe‘s recent activities and next steps

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Presentation Background

- LBST
  - is a Germany based research institute and consultant company
  - has supported, initiated, coordinated, moderated or participated in most European, many national and some international strategic studies on Hydrogen & Fuel Cells for Transport
- This presentation
  - was invited by the European Commission
  - does not necessary reflect the European Commissions views
  - outlines the development of energy and environmental benefit analysis of hydrogen & fuel cells (for transport) over time

Outline

- Recent energy & environmental analysis activities in Europe
- Outlook – from LEARNING to IMPLEMENTATION
- Chances for further international cooperation in systems analysis and benchmarking

Recent Energy & Environmental Analysis Activities in Europe

History of major EU technology analysis activities

- Auto Oil Program I and II
- Transport Energy Strategy for Germany (VES) (1999-…)
- GM-WtW Study Europe (2001-2002)
- CONCAWE – EUCAR – JRC WtW study (2003-…)
- EU Hydrogen Energy Roadmap HyWays (2004-2007)
- International hydrogen WtW-benchmarking HyWays-IPHE (2008-2009)
- National European Roadmap projects NorWays, GermanHy (2008-2009)
- EU Coalition Study (2009-2010)

Transport Energy Strategy for Germany (1999 - …)

- Initiate transparent learning about alternative fuels and drivetrains
- Develop national industry consensus involving auto and oil
- Reach out to national government

Interim Results & Recommendations
- January 2000

TES
Transport
Energy
Strategy

3 from 10 alternative fuels were preselected through analytical processes.

Fuel (s)	Advantages
LNG (CNG)	+ Closest to profitability (ICE) + Lowest CO_2-reduction cost
Methanol	+ Rel. low cost + Rel. simple infrastructure + Suitable in ICE and FC*
LH_2 (CGH_2)	+ Larger potential for primary energy + High CO_2-reduction potential + Suitable for ICE and FC + Local "zero emission"

*) In case all MeOH qualities are useable

Recommendations of Steering Committee in January 2000:

- Further investigate 3 fuels with the aim of selecting one
- strategy development with the assumed objective of replacing
  - 2.5% of fuel consumption in 2010
  - 15% of fuel consumption in 2020

with the selected fuel

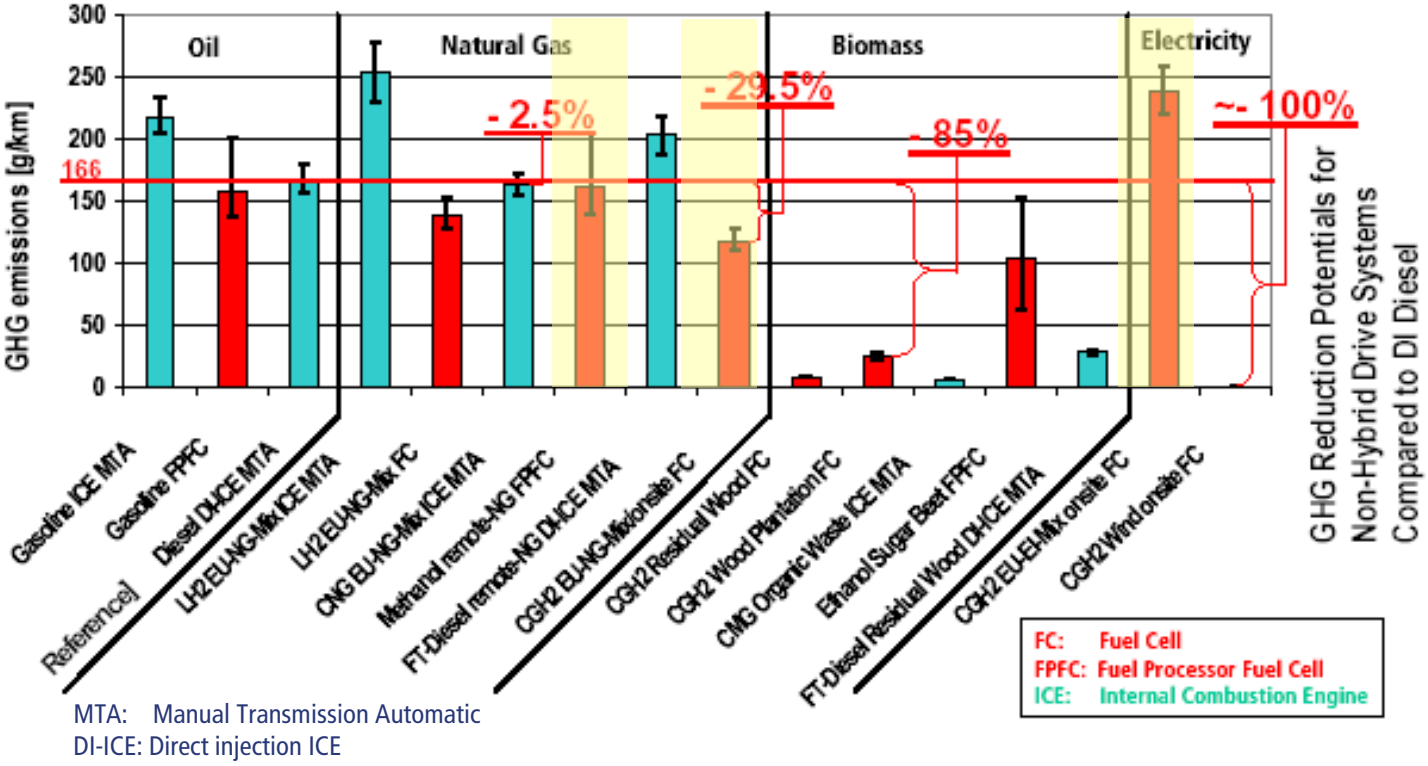
. First steps towards the expansion of TES throughout Europe

GM WtW-Study Europe (2001 - 2002)

Detailed learning on specific energy use, GHG emissions and cost of driving, e.g.:

- CNG has no significant GHG emission reduction effect vs Diesel-ICE only gasoline-ICE
- Natural gas can have relevant GHG emission reduction effect via H_2-FCEV
- H_2 and FCEVs not advantageous with grid electricity for most of Europe
- Clear advantages for hydrogen FCEVs for economic and environmental reasons!

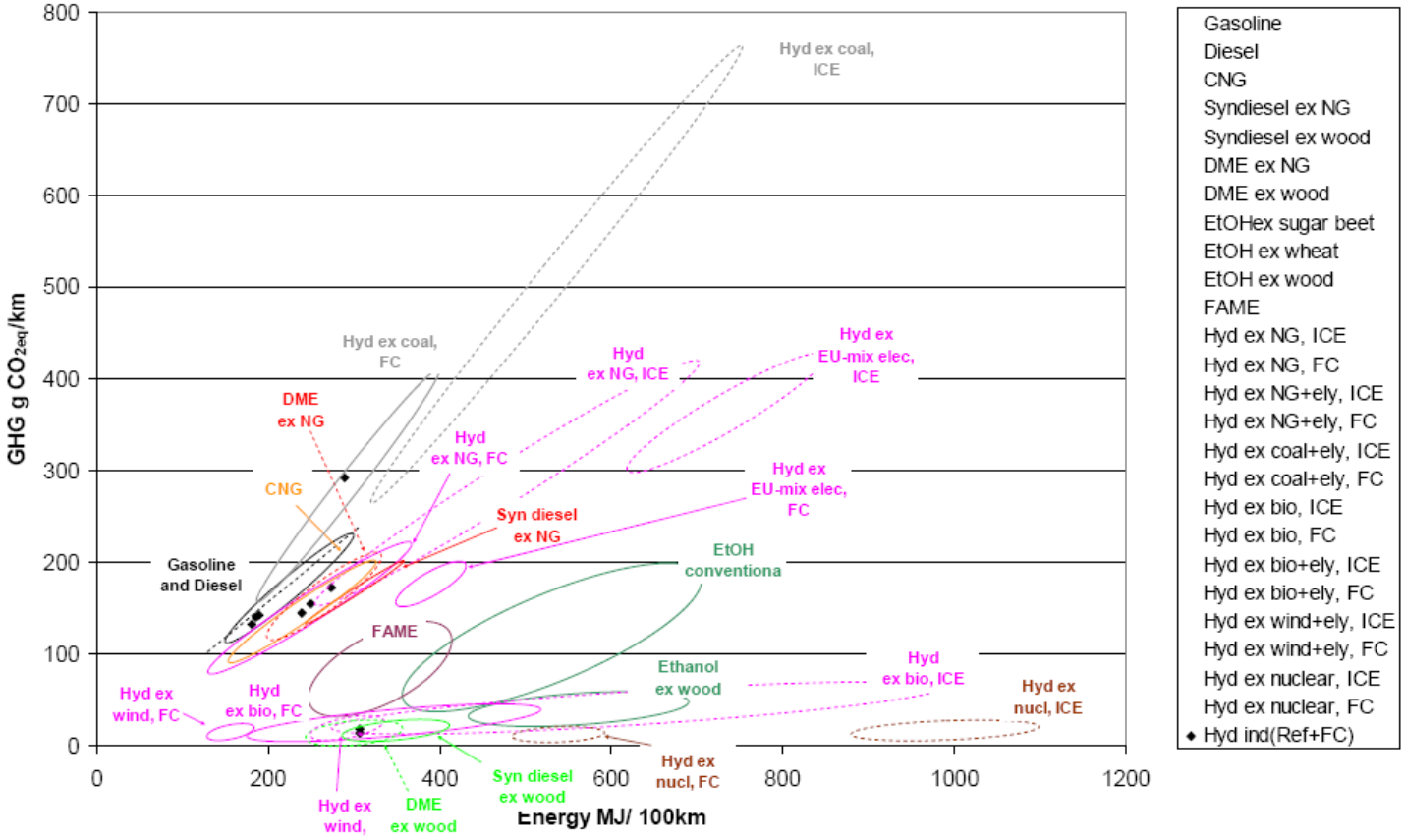
Full transparency!



MTA: Manual Transmission Automatic
DI-ICE: Direct injection ICE

CONCAWE – EUCAR – JRC Study (2003 - …)

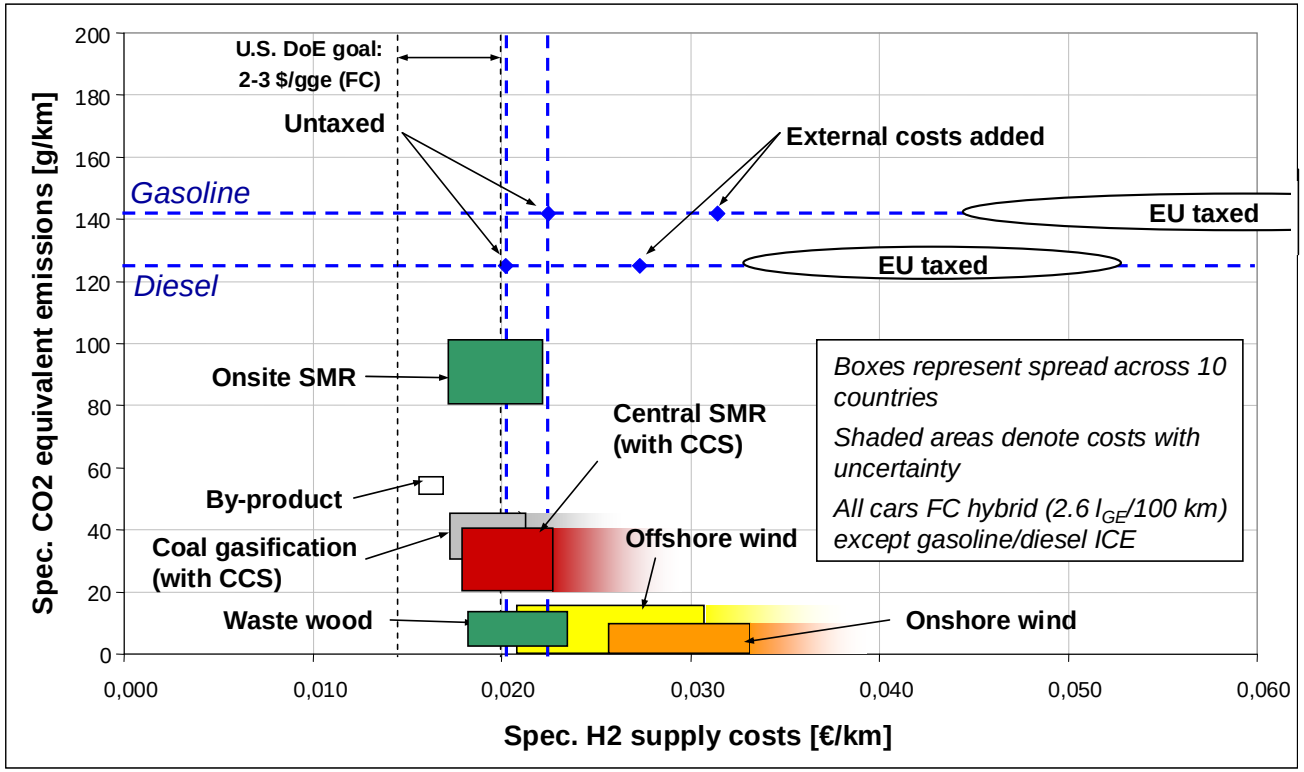
- Europe-wide auto and oil industry consensus on alternative fuels and drivetrains
- Only energy use and GHG emissions assessed, no business model developed
- Activity ongoing, update for E-mobility pending



EU Hydrogen Energy Roadmap HyWays (2004 - 2007)

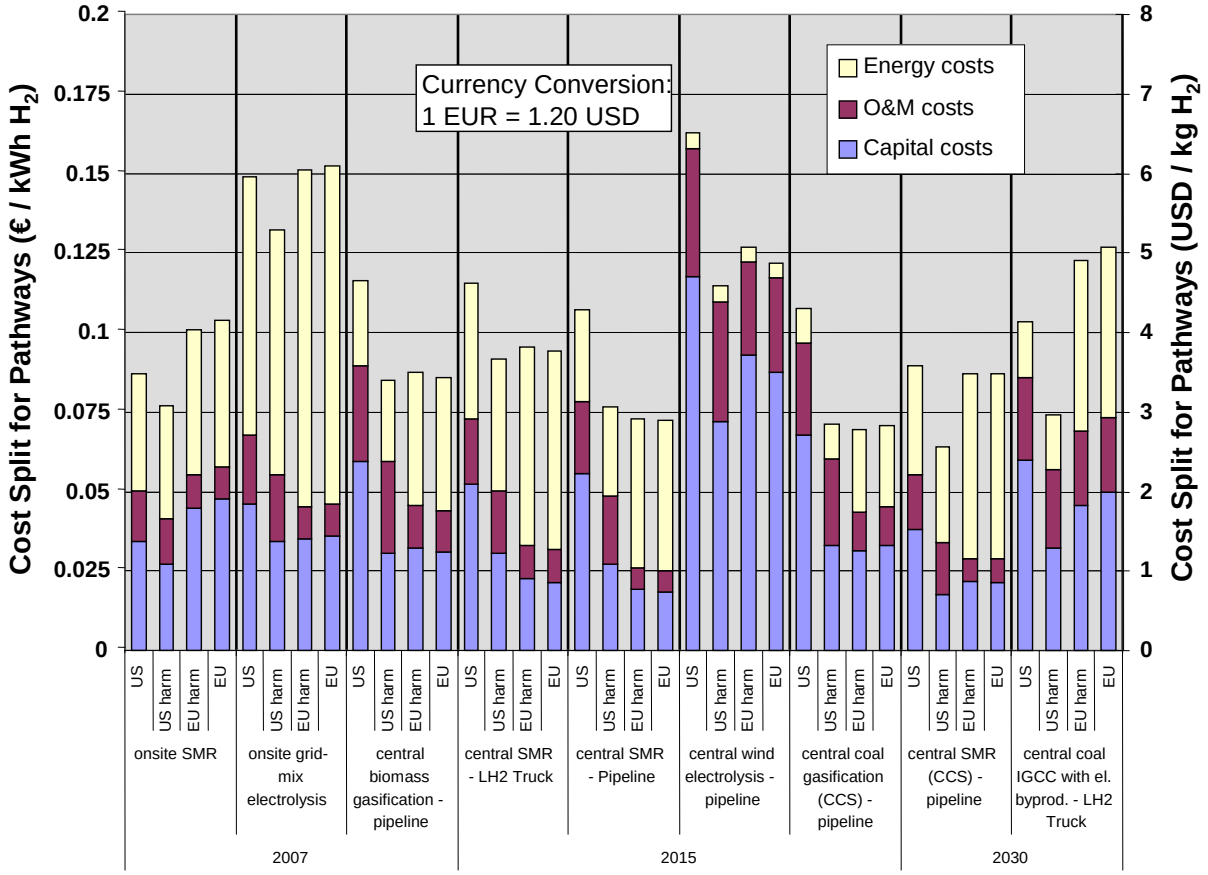
- Understand breadth of EU approaches for hydrogen in transport
- Back- and forecasting and wide actor involvement (industry, institutes, politics)
- Use of toolbox (technical, economic, emissions and policy impact modelling)
- Raise level of attention for hydrogen and fuel cells, no commercialization approach!

Prospect 2030 with forward looking assumptions



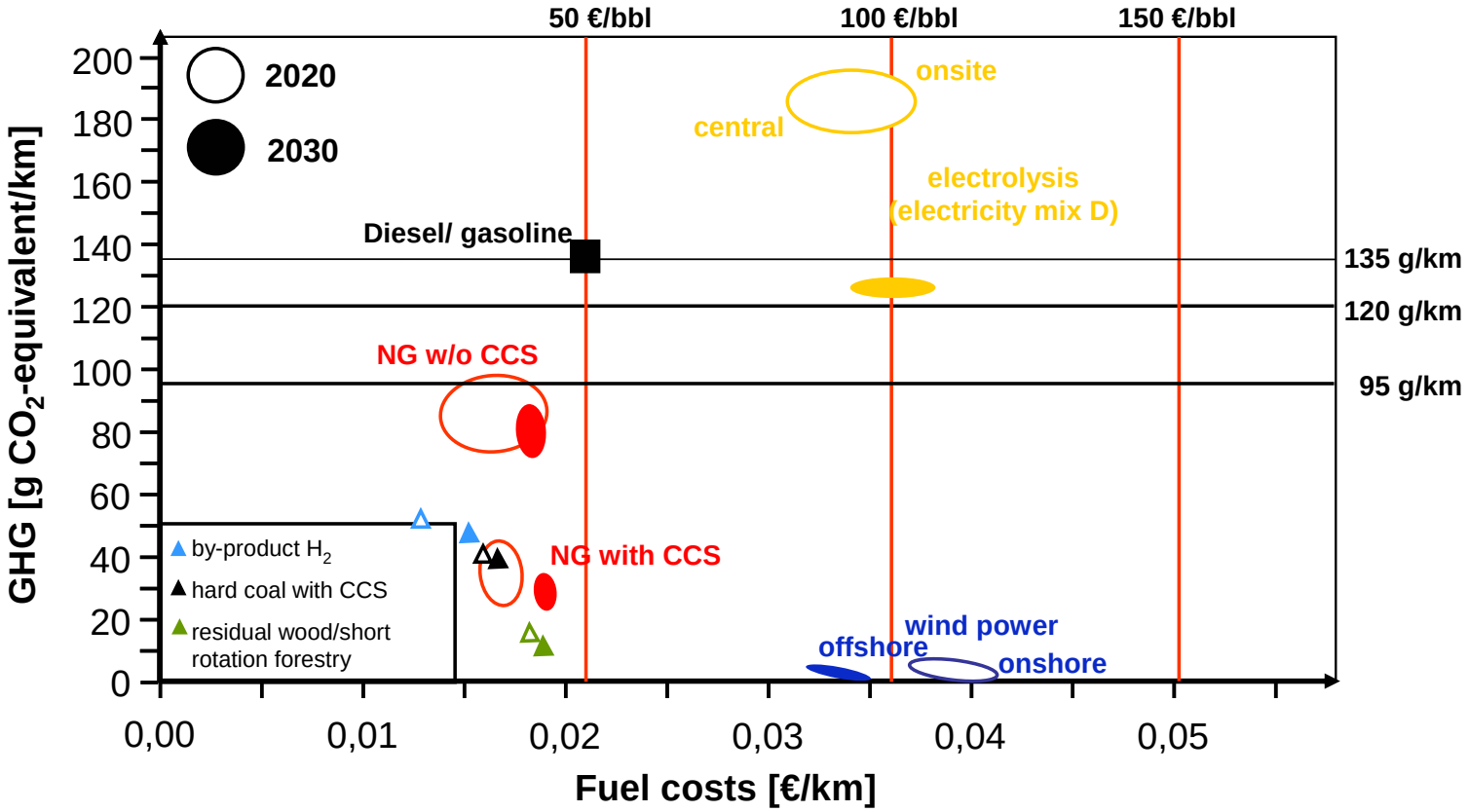
International Hydrogen WtW Benchmarking HyWays-IPHE (2008 - 2009)

- Initiate transparent benchmarking of WtW and other techno-economic modelling assumptions and results between U.S. DoE and EC
- Identify open issues for joint learning
- Understand that in spite of different modelling approaches assumptions and WtW analysis results are very similar (spec. GHG emissions, costs)



Hydrogen Energy Roadmap GermanHy (2008 - 2009) (1)

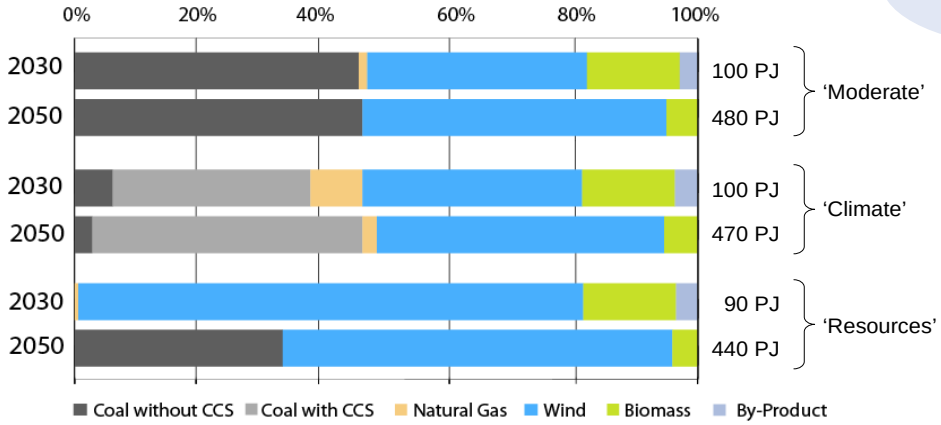
- Understand hydrogen‘s national resource base and impact on energy system and GHG-emission reduction
- Decision support for use of national hydrogen & FCEV funds for transport infrastructure



Hydrogen Energy Roadmap GermanHy (2008 - 2009) (2)

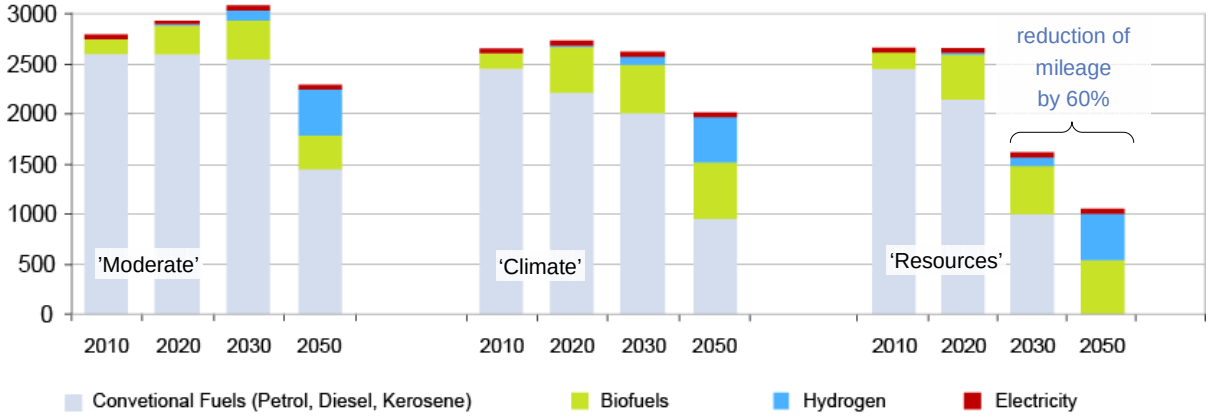
Energy use to produce hydrogen

shares of primary energy carriers in hydrogen production



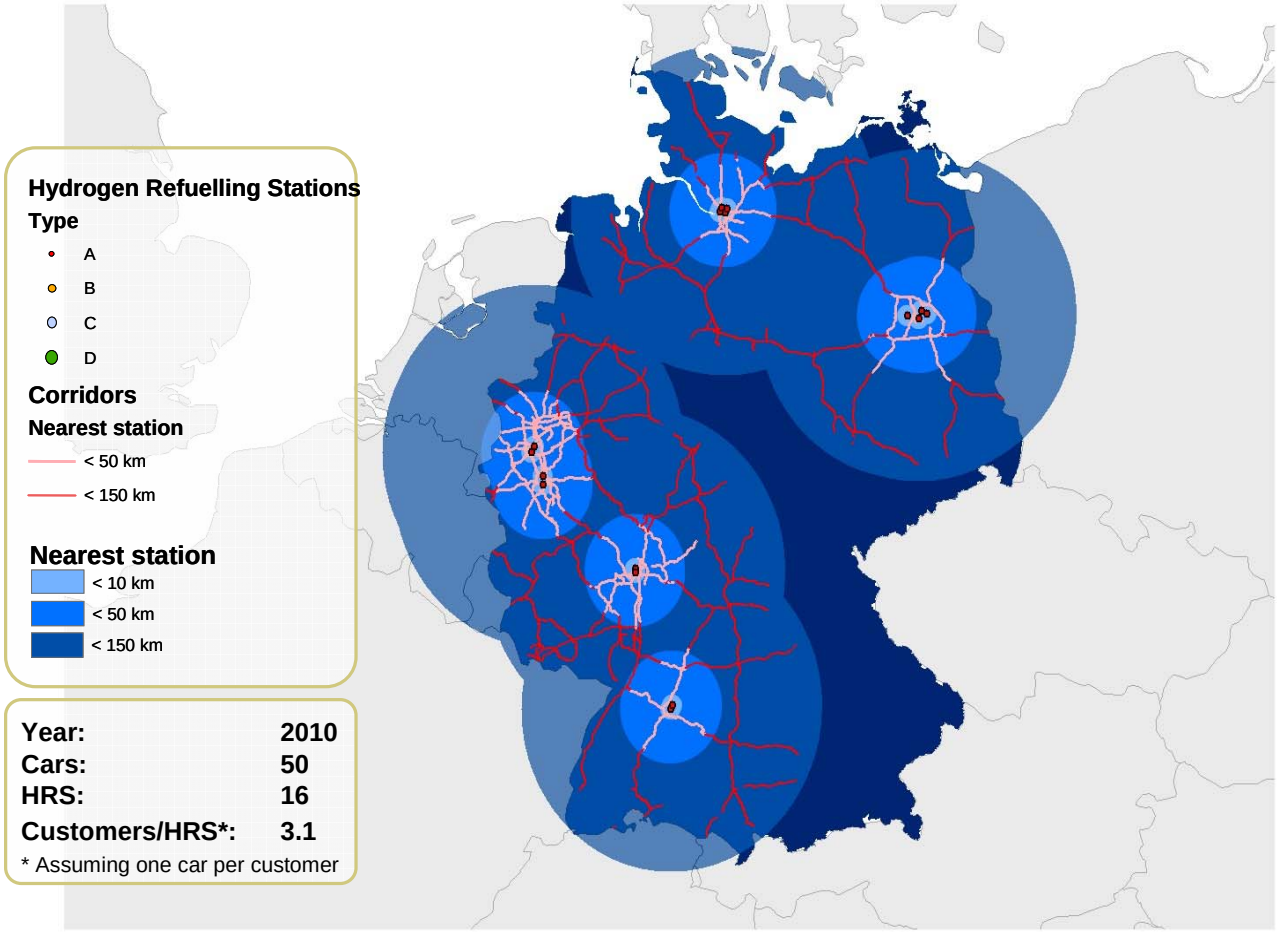
political imperative:
share of renewable energies
at least 50%

Final energy consumption of German transport sector [PJ/a]



Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2010



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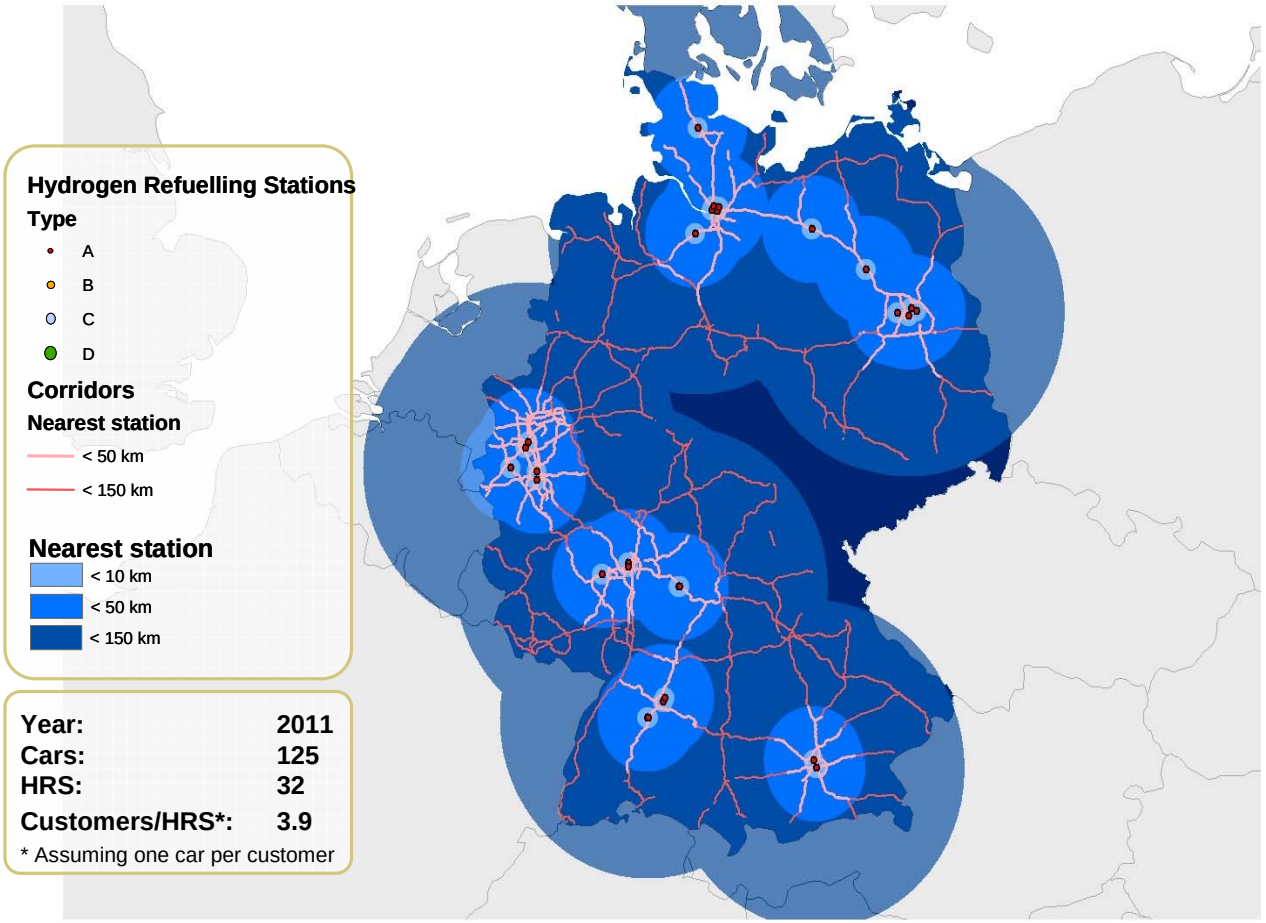

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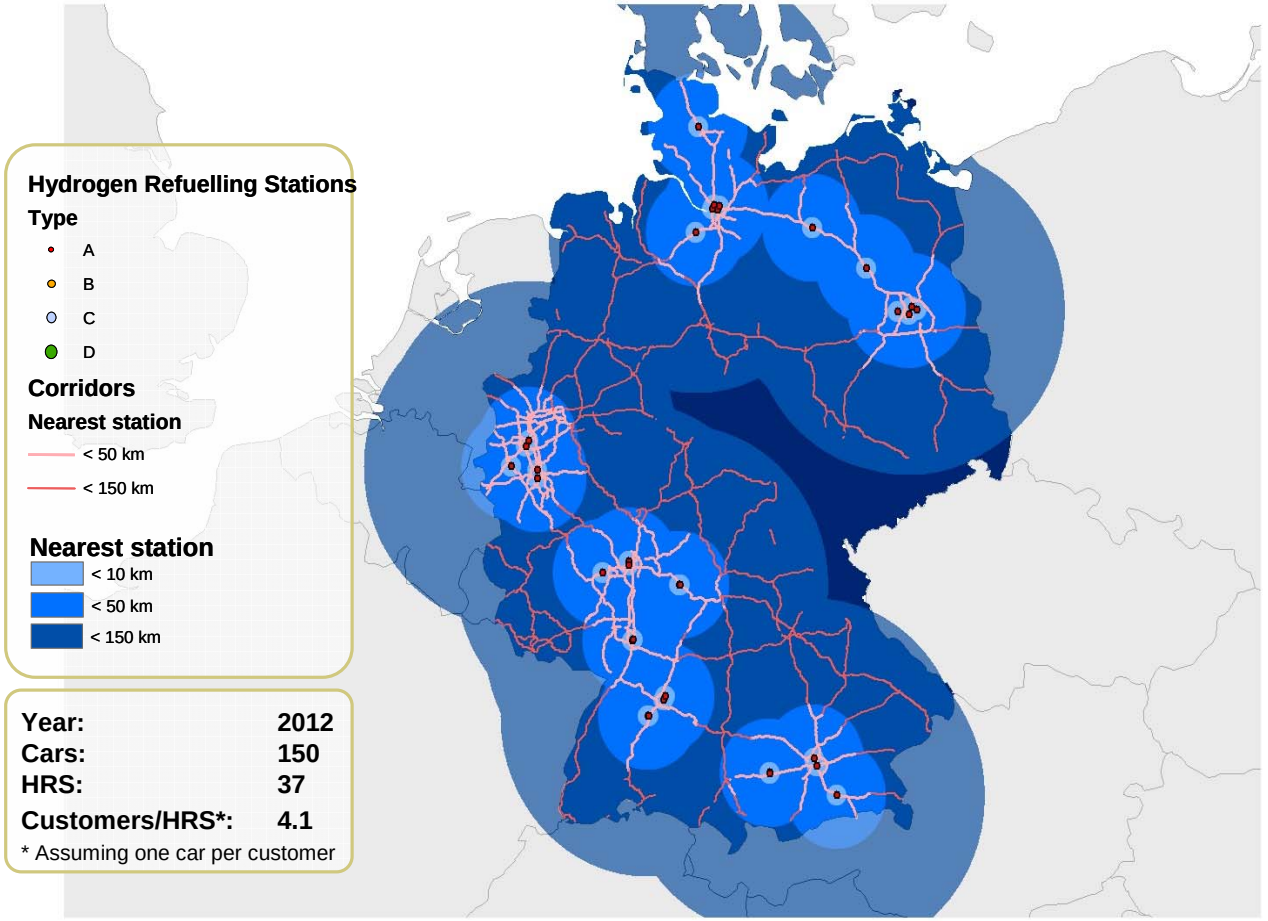

Detailed infrastructure roll-out analysis

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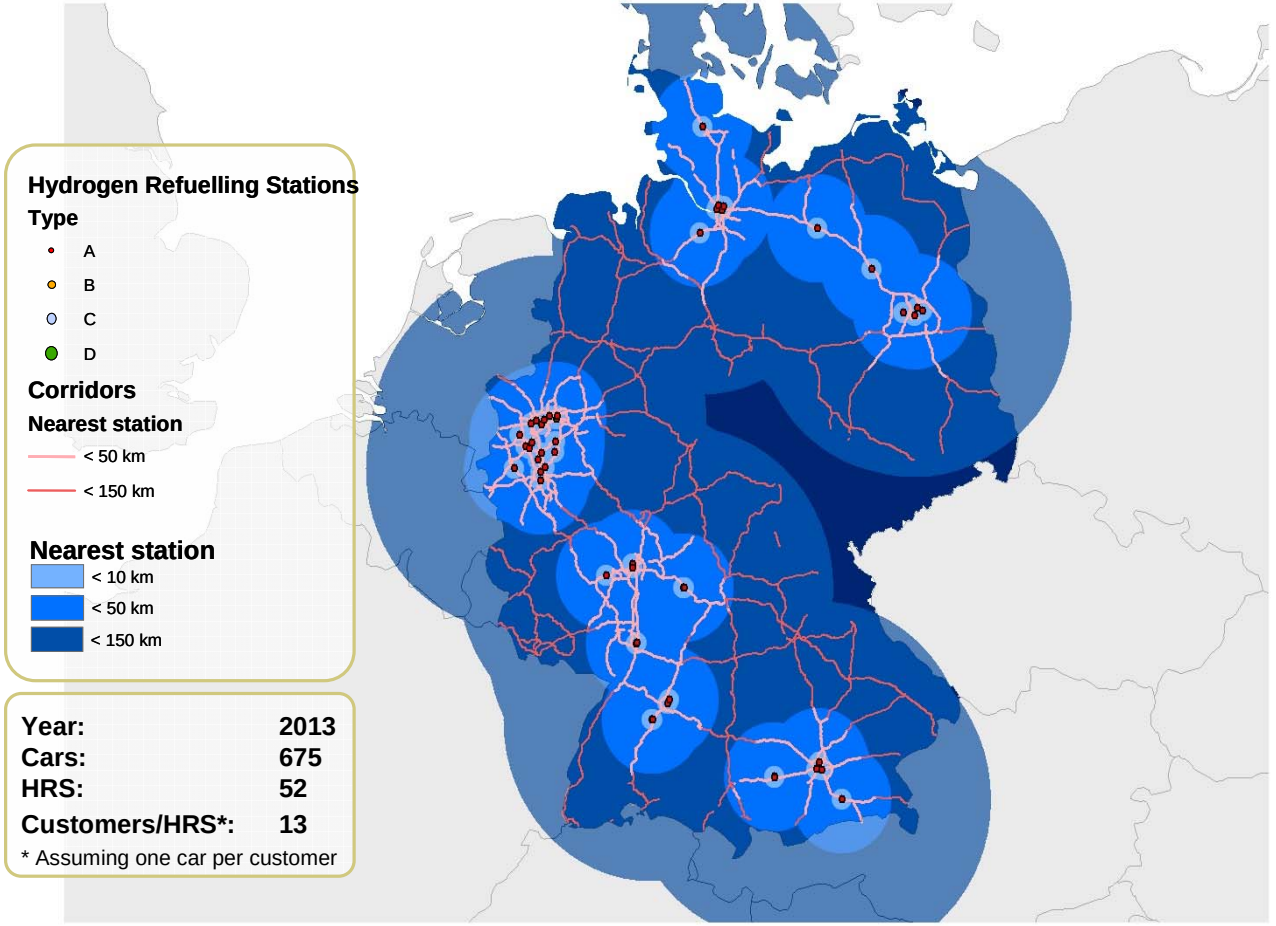
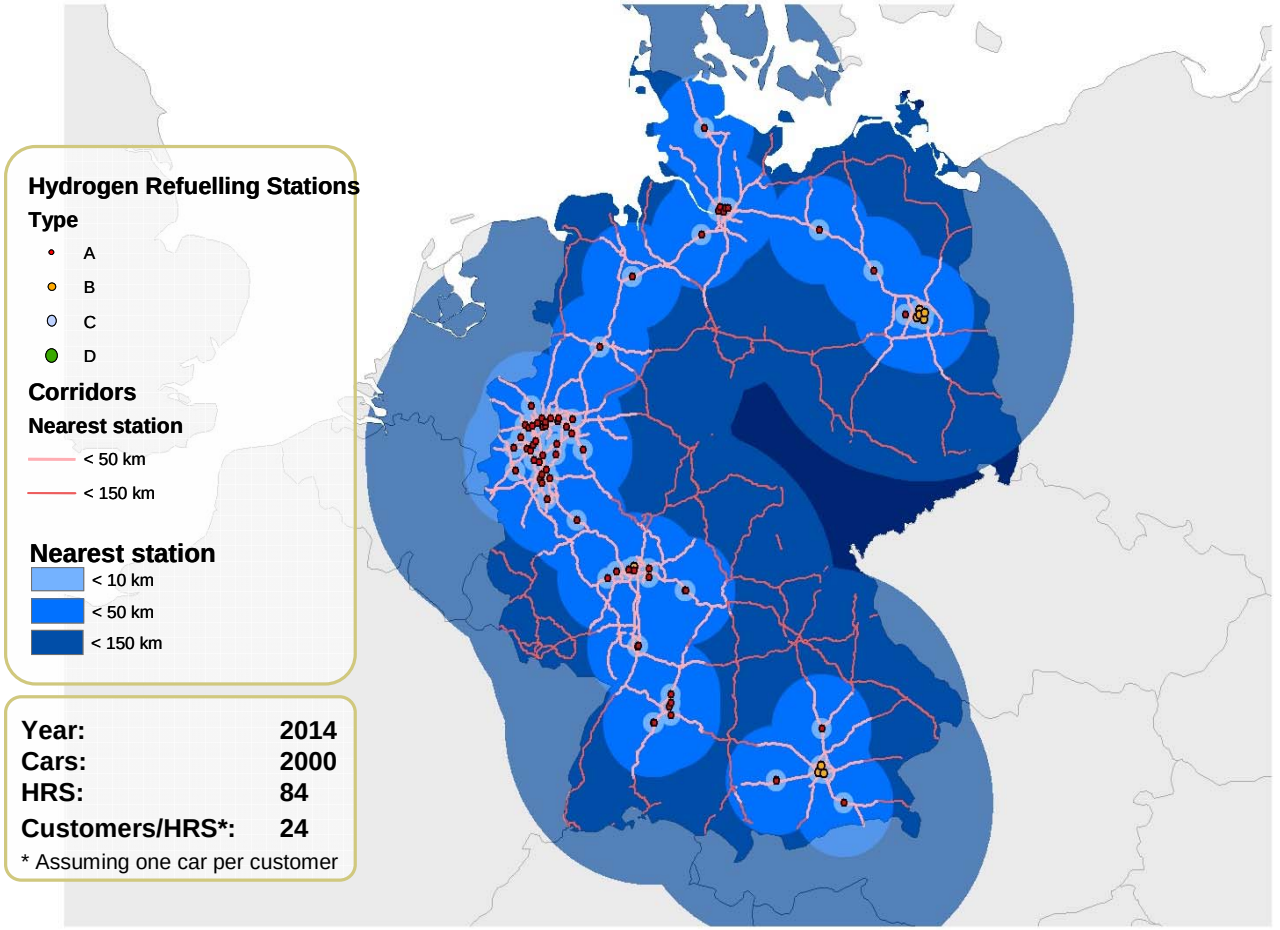


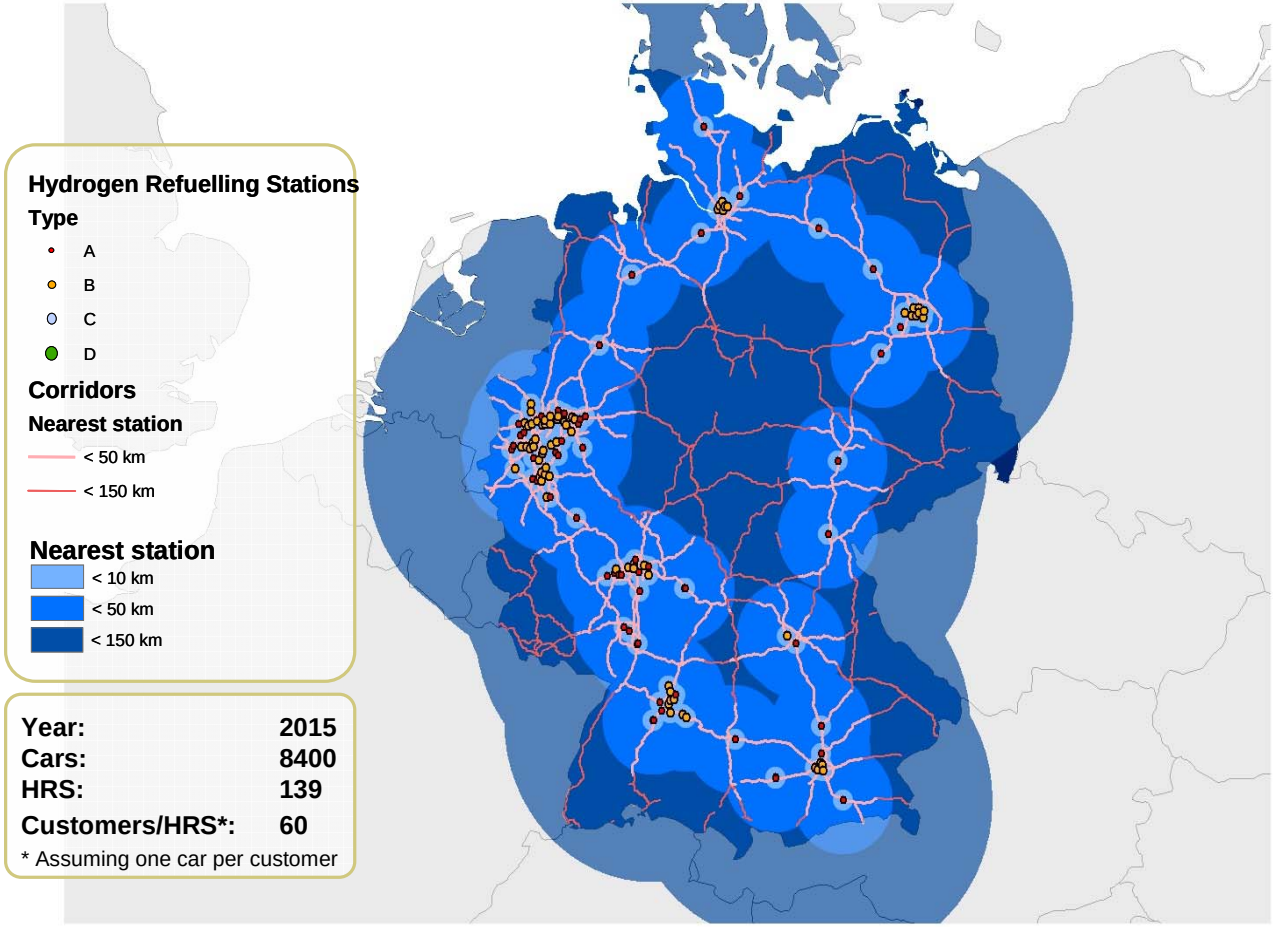
Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2014



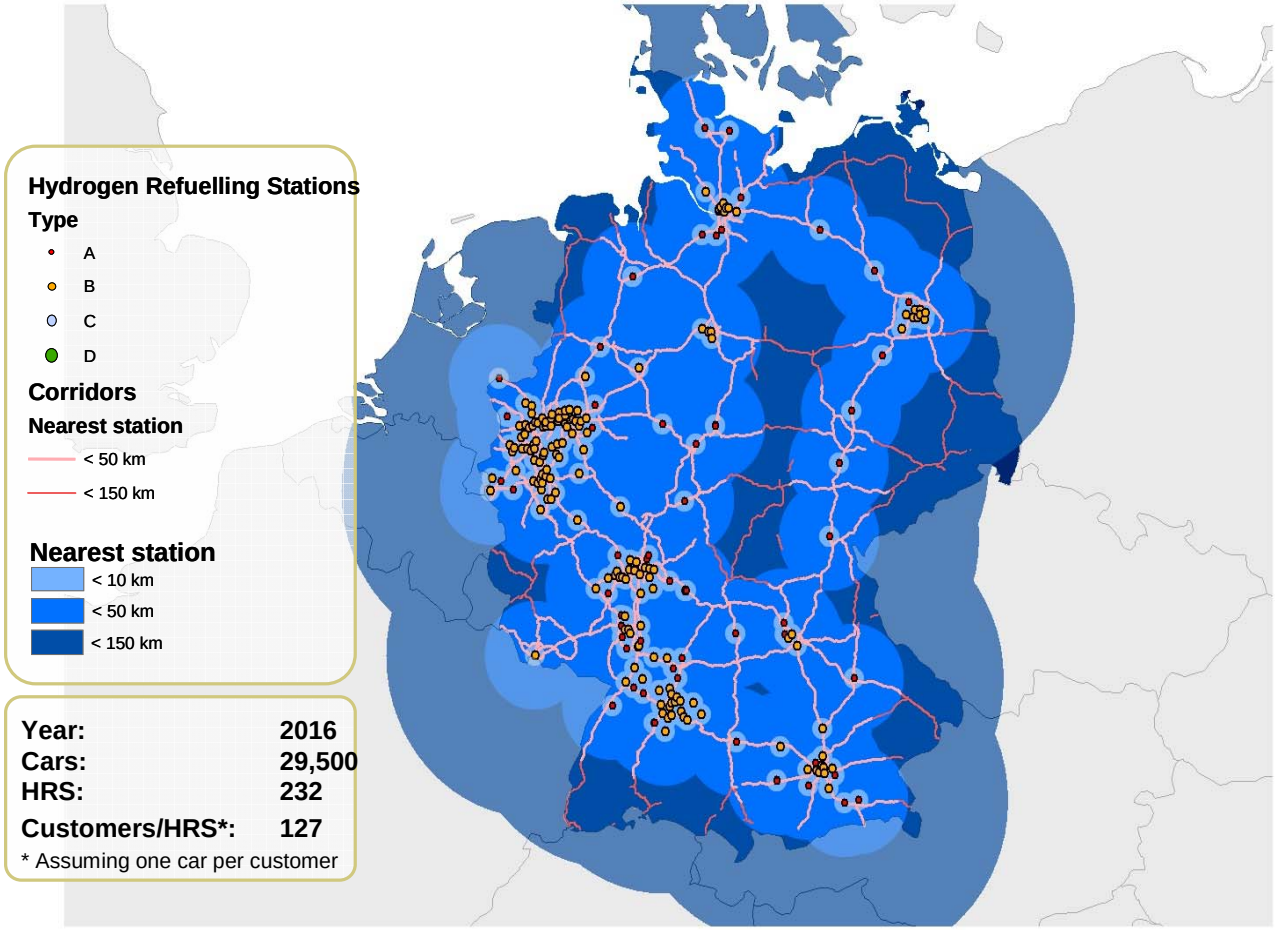
Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2015



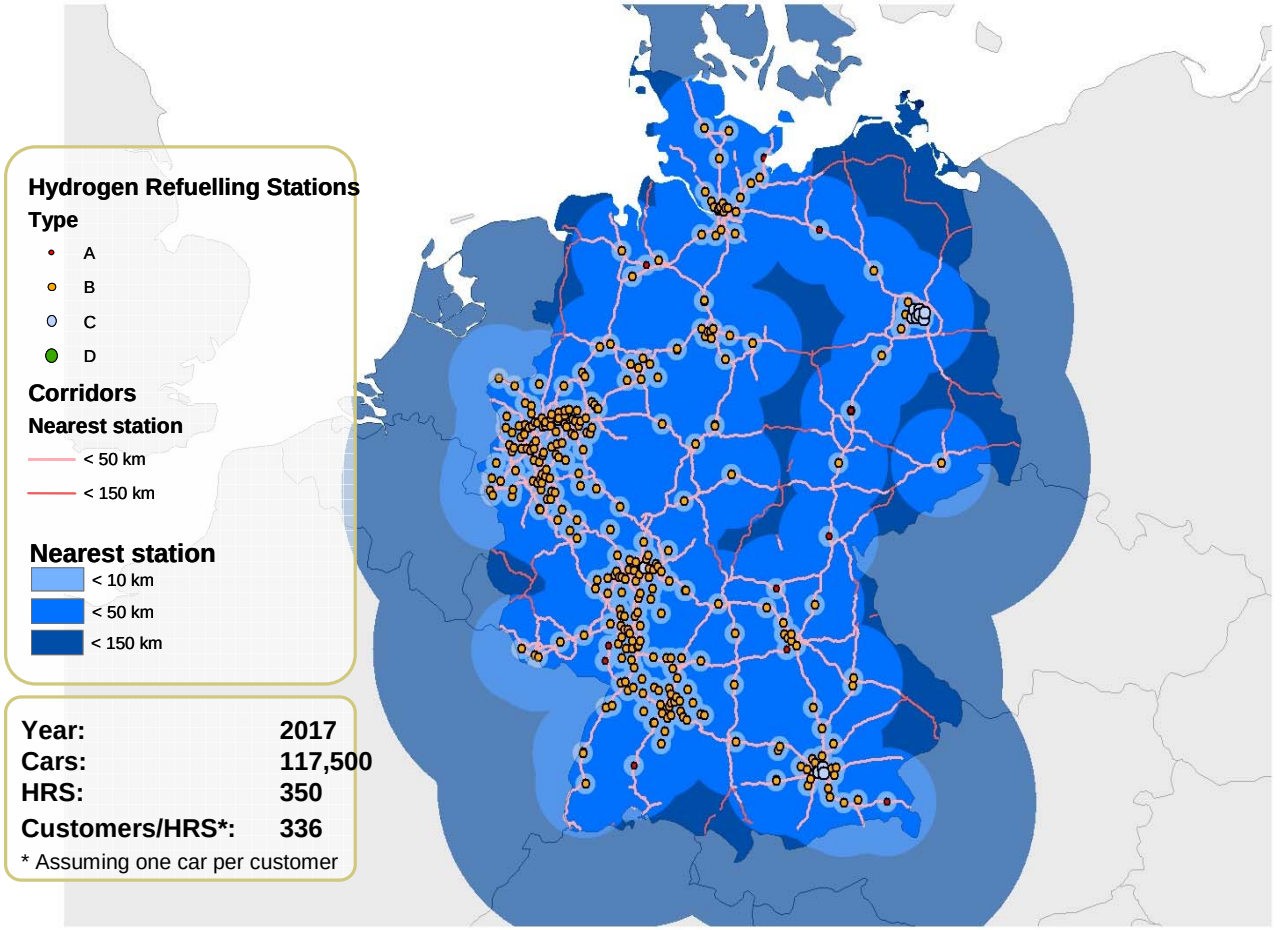
Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2016



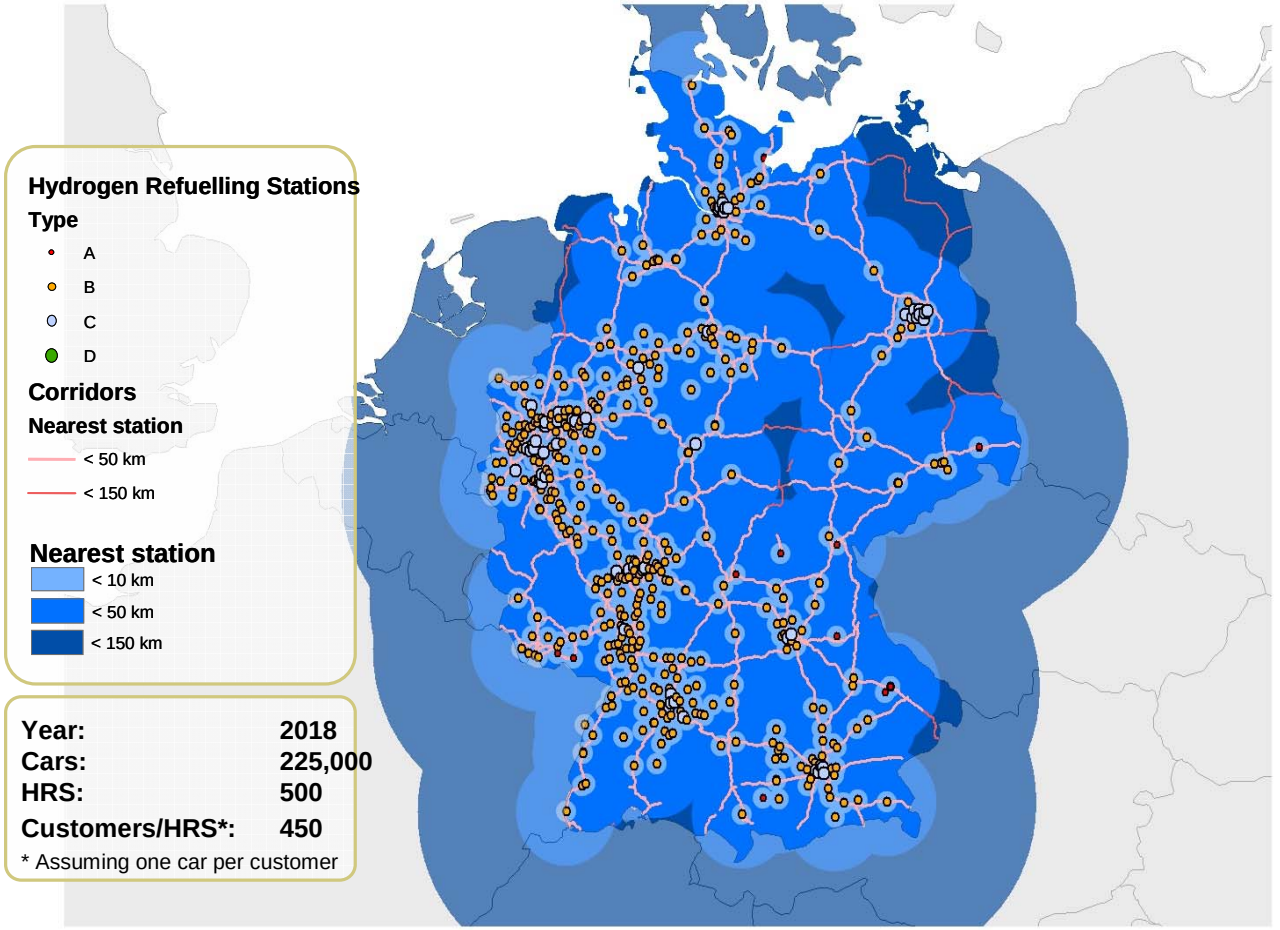
Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2017



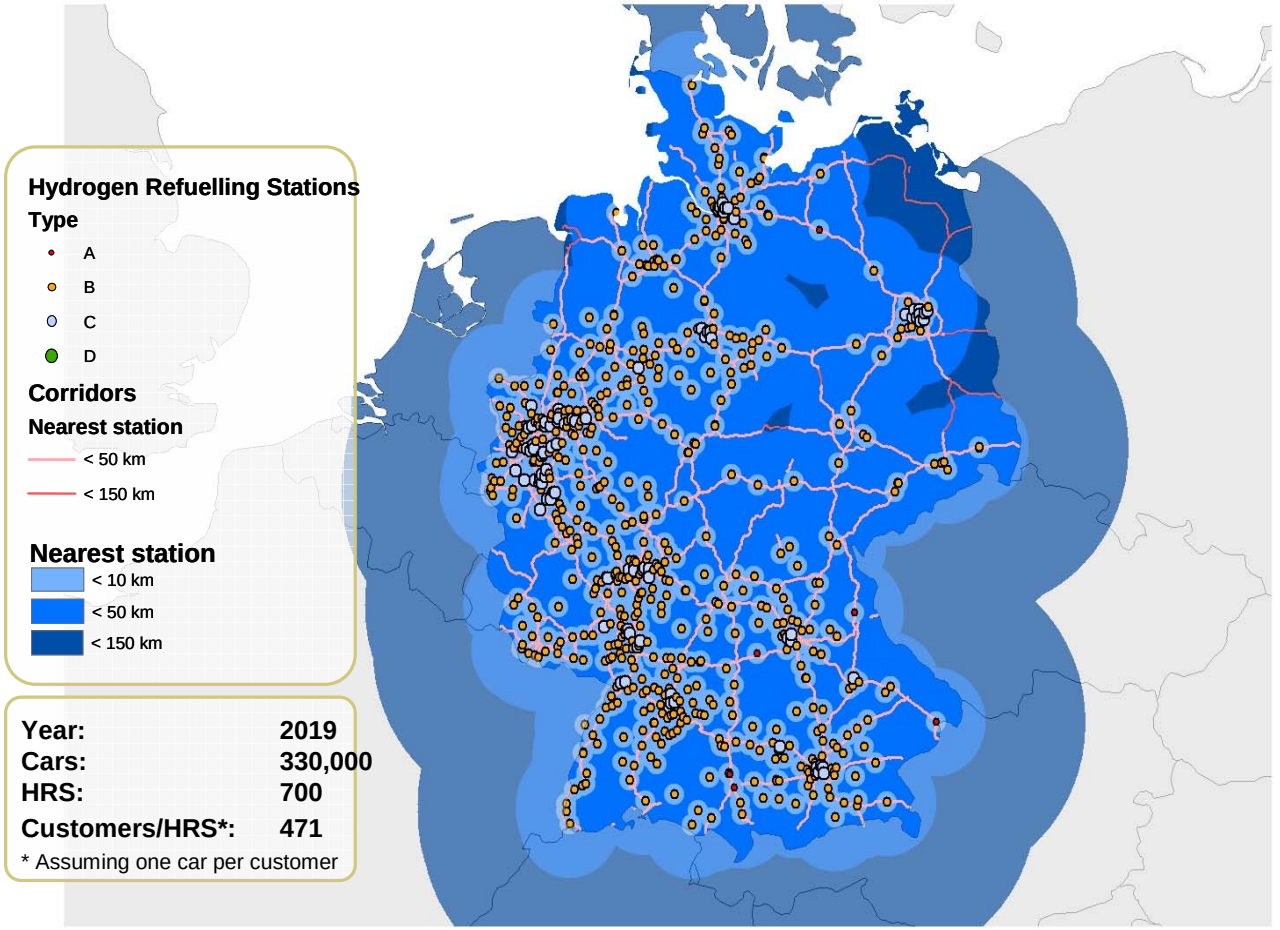
Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2018



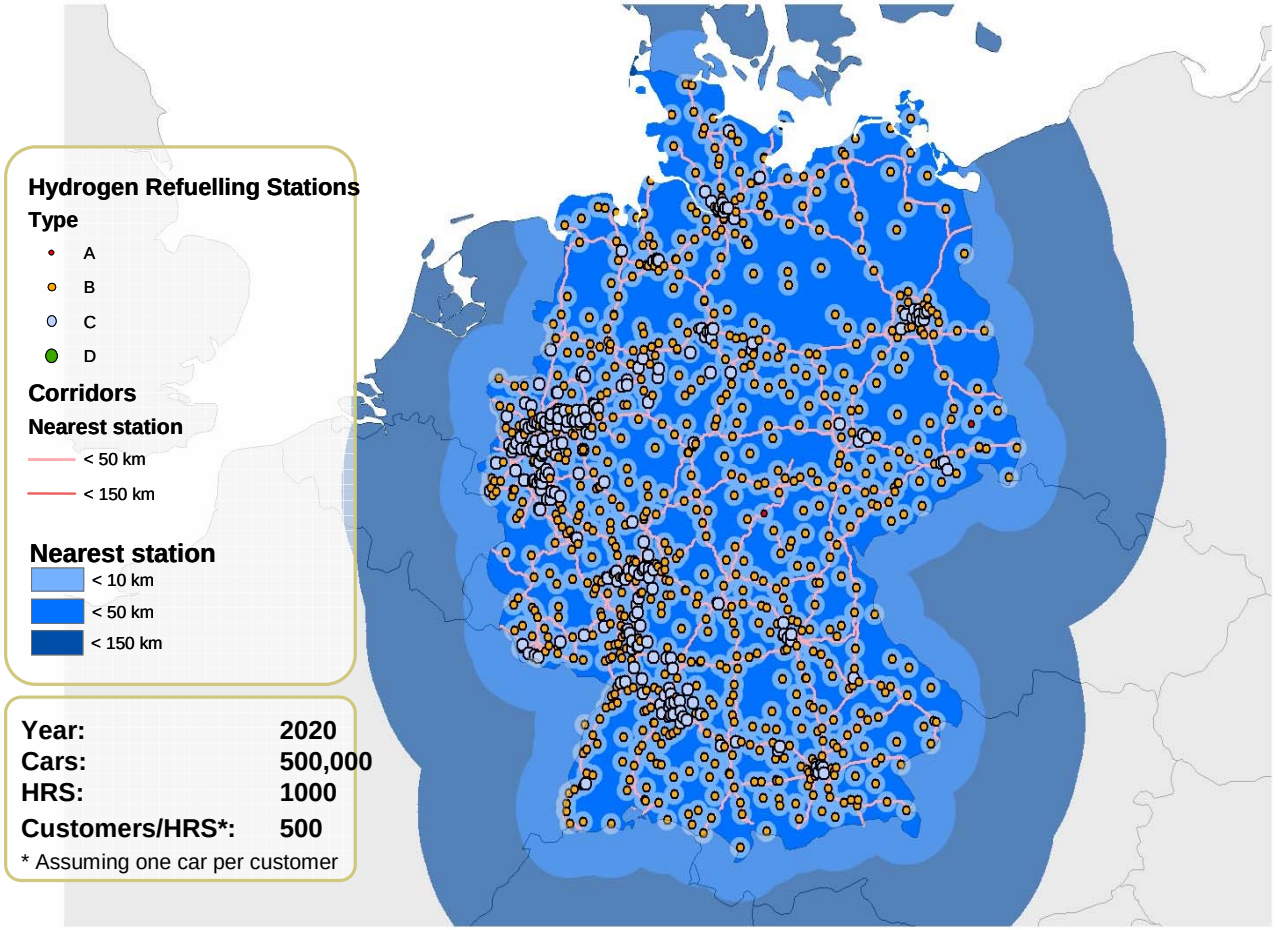
Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2019



Detailed infrastructure roll-out analysis

Refuelling station roll-out Germany 2020



Outlook
from LEARNING to IMPLEMENTATION

Europe‘s approach – from LEARNING to IMPLEMENTATION

National industry-wide and policy consensus on alternative fuels/drivetrains
(VES)

Europe-wide industry consensus on alternative fuels/drivetrains
(GM-WtW, CONCAWE/EUCAR/JRC)

National & EU roadmaps
(HyWays, NorWays, GermanHy, DutchHy, HYRREG…)

Installment of FCH JU (PPP)

Secure industry‘s strong commitment for business case
(EU Coalition Study)

Benchmark WtW analysis results worldwide
(NEDO-seminar, HyWays-IPHE)

Develop detailed policy support instruments to secure relevant public support

2000 2005 2010

Continuous in-depth learning on and benchmarking of specific and global energy use, GHG emissions, costs of driving and development of policy instruments

Europe‘s approach – from LEARNING to IMPLEMENTATION

- Technical learning has been tremendous over the last 10 years
  - FCEVs believed to reach technical goals by 2015 and cost goals by 2020
  - 70 MPa hydrogen storage decided for market introduction
  - Many options of hydrogen production to align CO_2 emissions and costs
  - Infrastructure roll-out preparation well under way
- BUT, a lot remains to be done, also by systems analysis support
  - Not all of industry agrees yet
  - Different industry stakeholders face different initial investment risks
  - Government intervention/policy measures required for risk sharing
  - Public incentives not all sufficient for OEMs to jump across risk fence
  - Joint industry and policy sector approaches to be improved/developed
  - Various pathways for decarbonization of hydrogen across Europe
  - RCS and safety needs wide harmonization towards commercial markets

Chances for further international cooperation in systems analysis and benchmarking

Further international cooperation in systems analysis

Comparison of

- efficiency of policy support options
- detailed infrastructure modelling
- lessons learnt from demonstration projects

Application of full LCA analysis

Synergies from use of hydrogen for transport and renewable energy storage

Extension of benchmarking with other countries

Thank you for your attention! Questions?