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Hydrogen Economy –

Gamechanger for the Process Industry

2. Deutsch-Russische Wasserstoff-Tagung, 8. Dezember 2021

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Current applications of hydrogen

- Hydrogen
  - Refineries 31%
    - Hydrocracking
    - Hydrotreating (Desulfonation etc.)
  - Chemical Industry 63%
    - Ammonia
    - Methanol
    - Polymers
    - Polyurethane
    - Oxoalkohols, Fatty Acids, SNG
  - Process Industries 6%
    - Reduction of Iron
    - Protective Gas
    - Glass Production
  - Liquid Hydrogen <1%
    - Rocket Fuel
    - Semi-Conductor Industries
    - Transport (FCEV)

Quelle: DOE, Fair-PR, Linde

Future Applications of Hydrogen in Different Sectors

- Electricity generation (compensation of fluctuating renewables)

- Industrial applications
  - Iron & Steel (DRI, substitute in BF)
  - Chemical industry

    (E-chemicals as alternative feedstock, plastics recycling)
  - High-T process heat (i. e. glass industry)

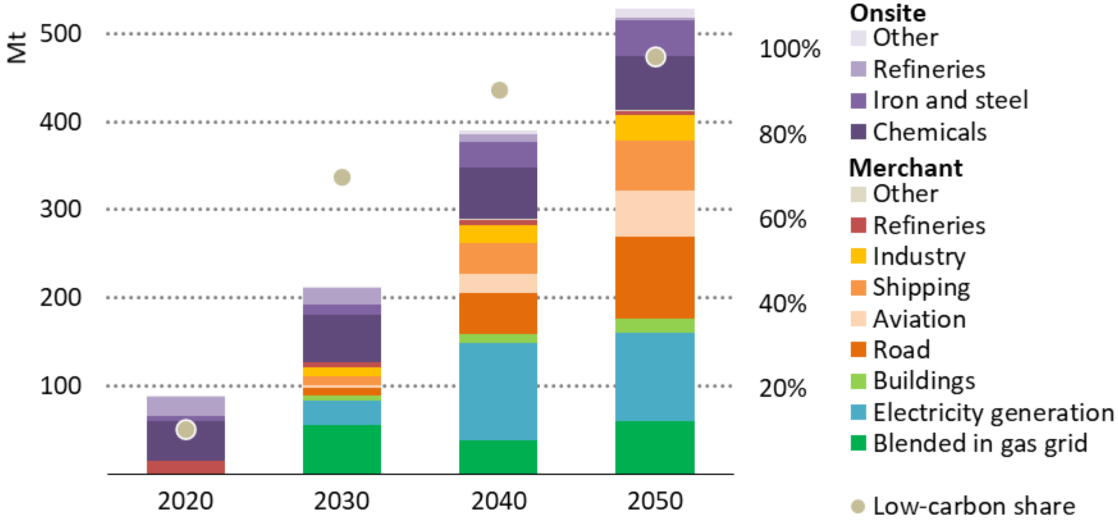
- Transport applications (fuel cells)
  - Road: heavy duty transport, vans, cars
  - Rail: Passenger trains, freight trains, …
  - Marine transport
  - Aviation (short distances)

  - E-Fuels for combustion engines

- Household and commercial
  - Heating

Hydrogen - Great Expectations

- Use of hydrogen expands by factor 5
- New applications (steel, transport, fuels, electricity…)
- Initially easy to implement cases
- Finally in all sectors



International Energy Agency (2021), Net Zero by 2050, IEA, Paris
Fig. 2.19 Global hydrogen and hydrogen-based fuel use in the NZE
The initial focus for hydrogen is to convert existing uses to low-carbon hydrogen; hydrogen and hydrogen-based fuels then expand across all end-uses

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Roadmap Chemie 2050

Towards a GHG neutral chemical industry in Germany

https://dechema.de/dechema_media/Downloads/Positionspapiere/2019_Studie_Roadmap_Chemie_2050-p-20005590.PDF
https://www.future-camp.de/de/publikationen/Studie-Roadmap-Chemie-2050_VCI.pdf

Possible developments for the chemical industry in Germany

- **Complete accounting of carbon (emissions)**

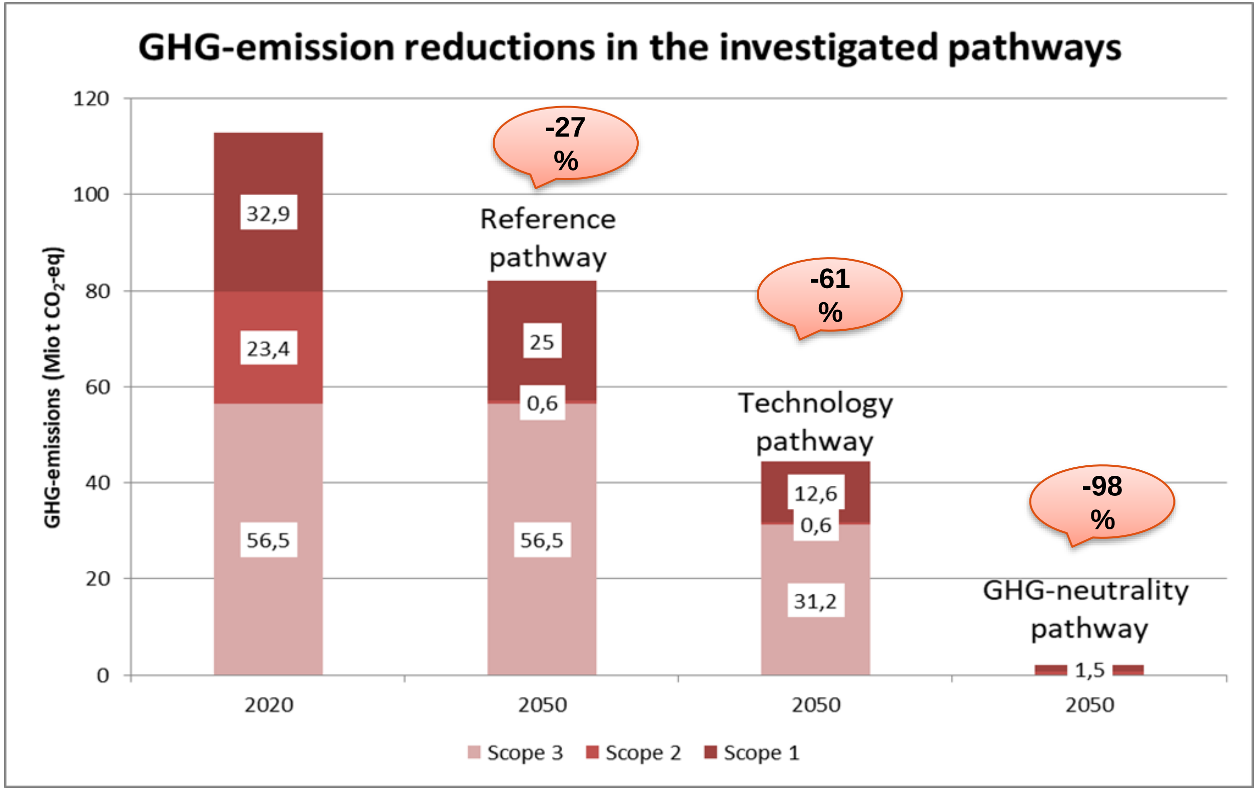
  Scope 1: Process-and energy-related emissions in the chemical industry

  Scope 2: Emissions caused by external electricity and district heating

  Scope 3: Emissions caused by carbon content of products (**NEW**)

- **Three transformation pathways**
  - Reference pathway
  - Technology pathway
  - Greenhousegas-neutrality pathway

GHG-emissions for the different pathways



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Technologies and technology options (TRL≥6)

Chlorine-alkaline electrolysis (Cl_2)

Hydrogen production (H_2)

- Steam reforming of natural gas
- Electrolysis of water
- Pyrolysis of methane

Synthesis of ammonia (NH_3)

- Conventional synthesis with natural gas
- Electrolysis of water and air separation
- Pyrolysis of methane and air separation

Synthesis of urea ($(NH_2)_2CO$)

- With conventional ammonia synthesis
- With alternative ammonia synthesis and CO_2-sources

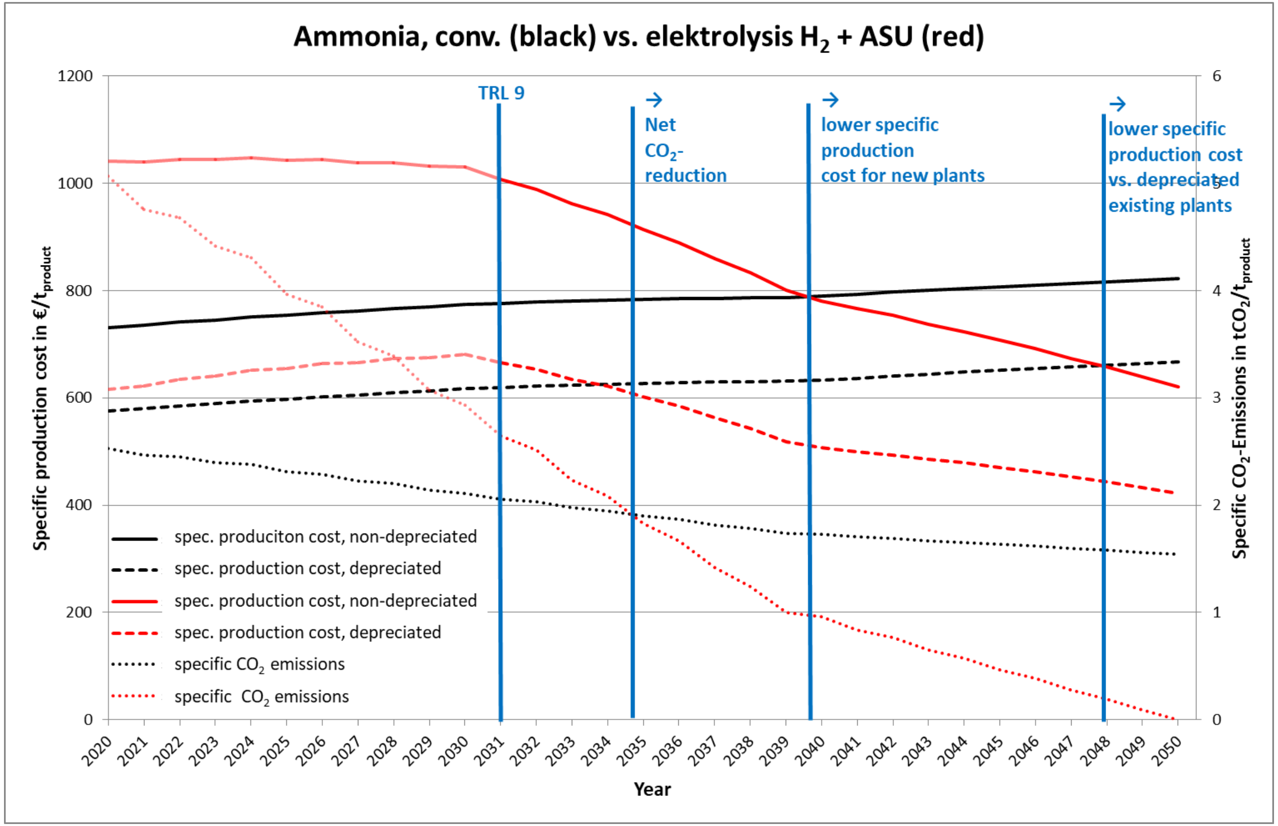
Synthesis of methanol (CH_3OH)

- Conventional via synthesis gas and fossil fuels
- Electrolysis of water and CO_2-sources
- Pyrolysis of methane and CO_2-sources
- From biomass
- Electrical heating

Olefines and Aromatics (Cracker)

- Conventional from naphtha
- Electrical heating
- Synthetic naphtha
- Chemical recycling of plastics via pyrolysis or gasification

Evaluation of new vs. conventional technology: Cost and CO_2-parity



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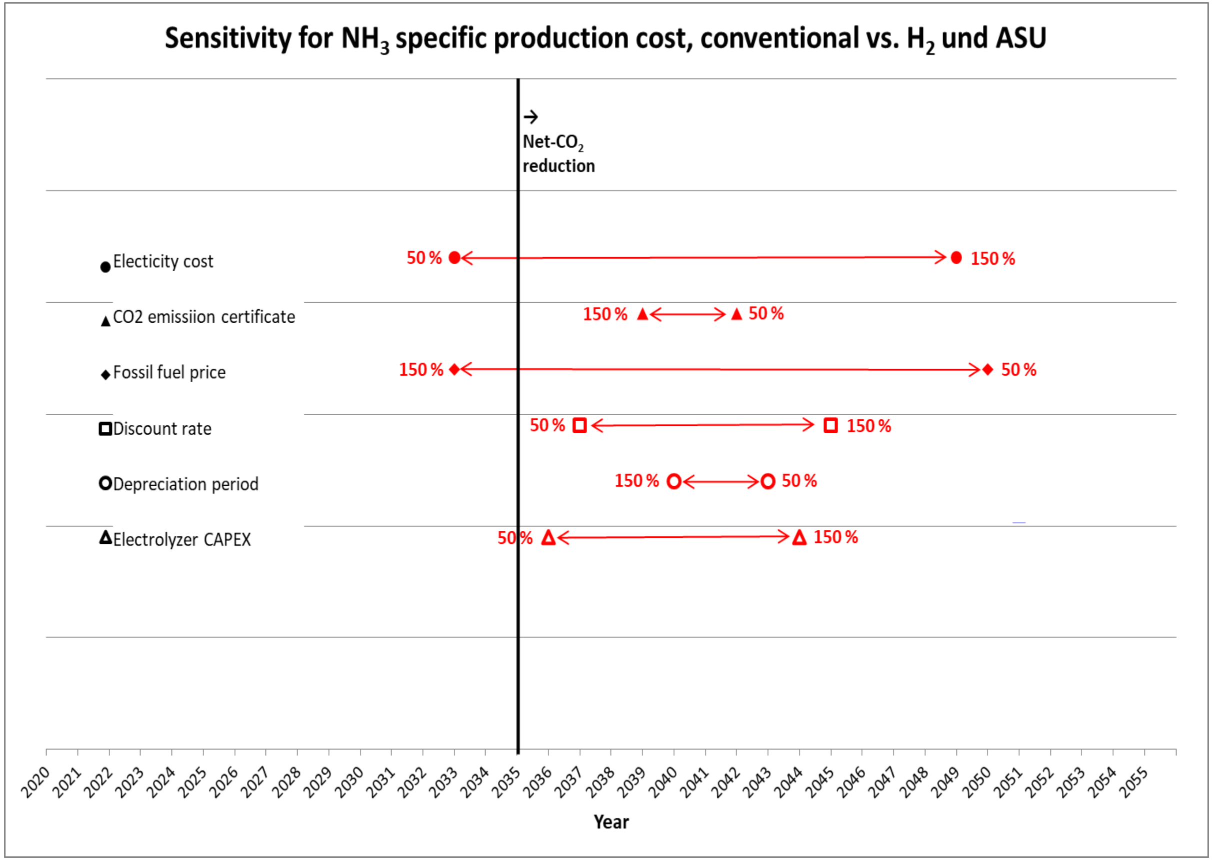
Evaluation of new vs. conventional technology: Sensitivity analysis



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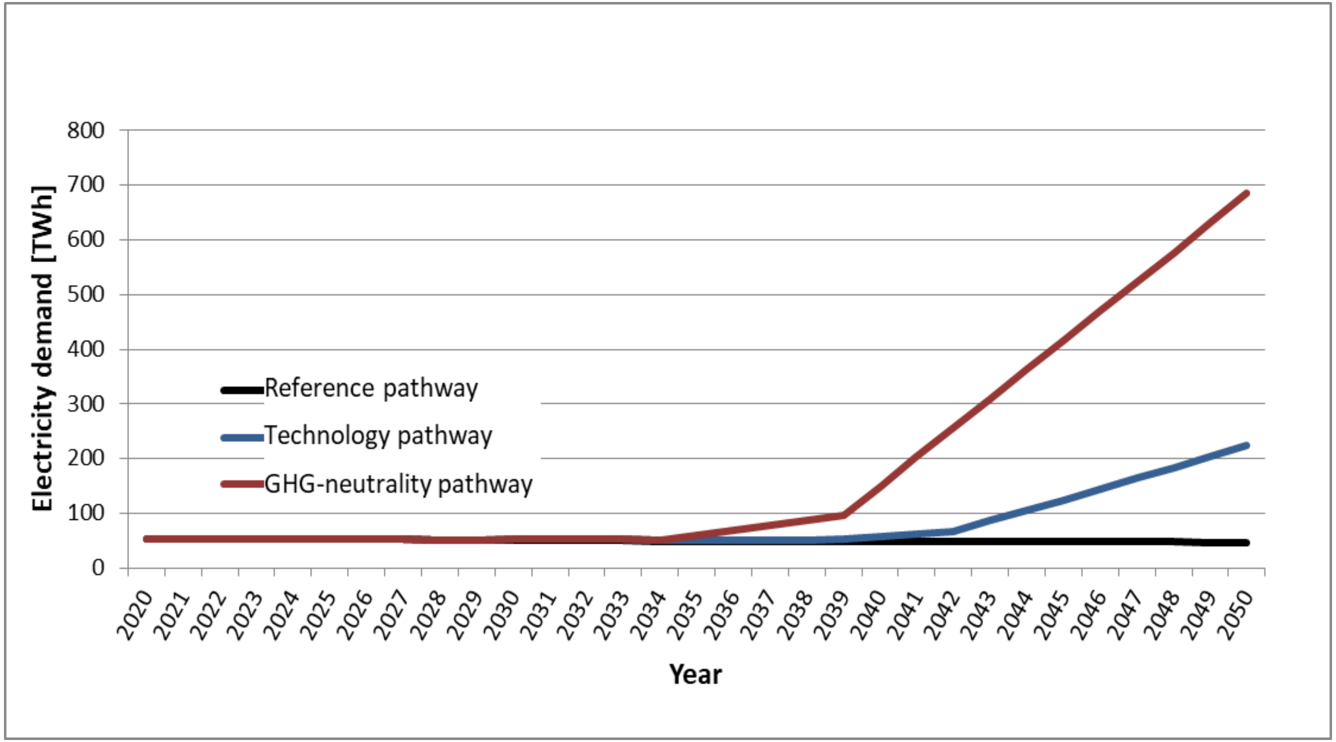
Comparison of pathways: Electricity demand



Conclusions

- A GHG-neutral chemical industry is possible
- Challenging conditions (low electricity price, CO_2, …)
- No silver bullet, all contributions necessary:
  - Quick shift to renewables for combined heat & power generation
  - Extensive mechanical and chemical recycling of plastics
  - Synthetic feedstock via CO_2 and H_2 → large demand for renewable electricity (> 600 TWh)
  - High investment volumes from 2040 onwards required
  - Residual emissions need to be compensated
- New infrastructures required (electricity, H_2, CO_2)
- Significant GHG impact on budget comes late
- International competetiveness challenging, due to significantly higher cost for base chemicals compared to today

Hydrogen for the Defossilisation of Industrial Sectors and Transport - Challenges

- Matching the volumes of hydrogen generation and application

- Availability of renewable energies (including social acceptance of wind parks)
- Import as most important option
- Large scale electrolysers

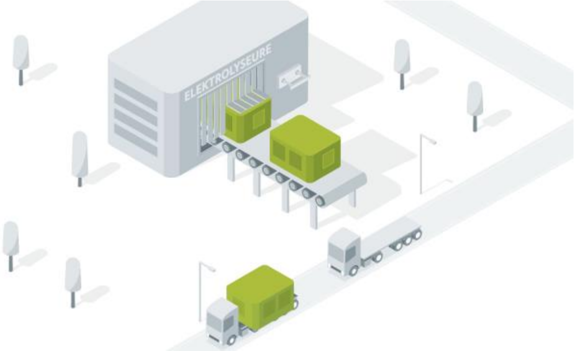
- Efficient (direct) chemical conversion processes (for synthetic fuels and chemicals)

- High demand for precious and rare earth metals (wind turbines, PV, electrolysers)
  Low carbon technologies = high metal dependency*

* Source: James Clark, Department of Green Chemistry, Centre of Excellence - University of York/UK

The Hydrogen-Initiave of the German Government – Flagship Projects / Platforms

Wasserstoff
Leitprojekte
Grün. Groß. Global.



H2Giga: Ramp-up production

(Ramp-up production capacities for electrolysers towards gigawatt scale/ AE, PEM, HT-SOE)

Budget: ~ 480 Mio. €

H2Mare: Offshore *(Integration of H_2 electrolyzer within offshore wind turbine/ offshore PtX processes)*

Budget: ~ 150 Mio. €

- ## TransHyDE: Transport solutions for green hydrogen *(Pressurized, liquefied or via chemicals/via ship, pipeline or trailer)*

  Budget: ~ 140 Mio. €