Wuppertal Institut

Hydrogen Economy
German concepts in transport, energy, buildings and industry

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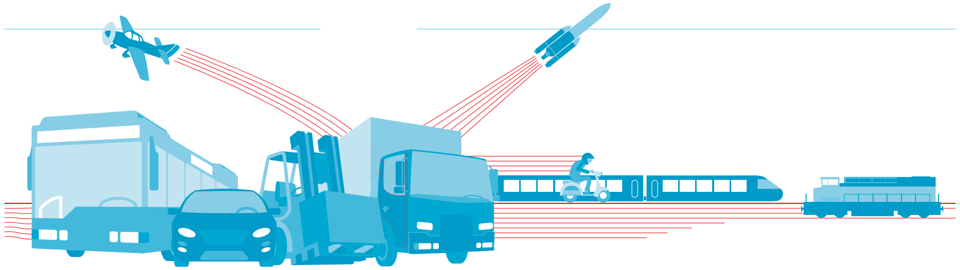
Based on:
Prof. Dr. Manfred Fischedick, Wuppertal Institut, 2019
and
German Japanese Energy Transition Council (GJETC) 2019

September 25th, Tokyo 2019

Use cases of hydrogen

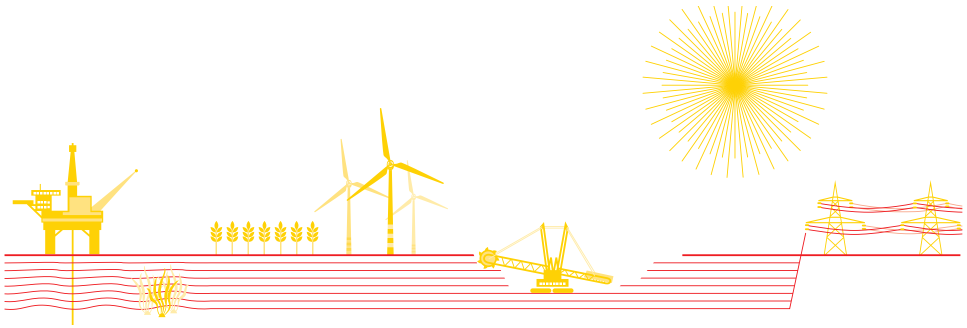
Selected experiences in Germany

Mobility applications

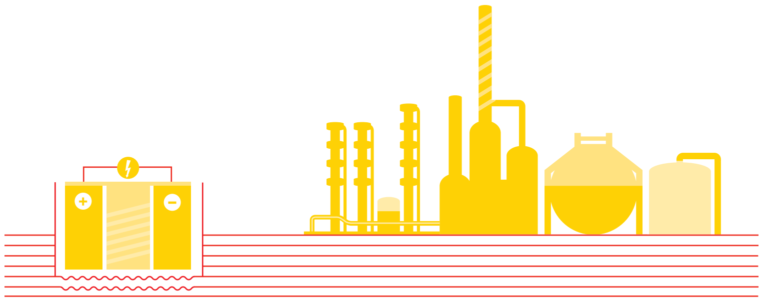


Stationary applications

Applications at system level

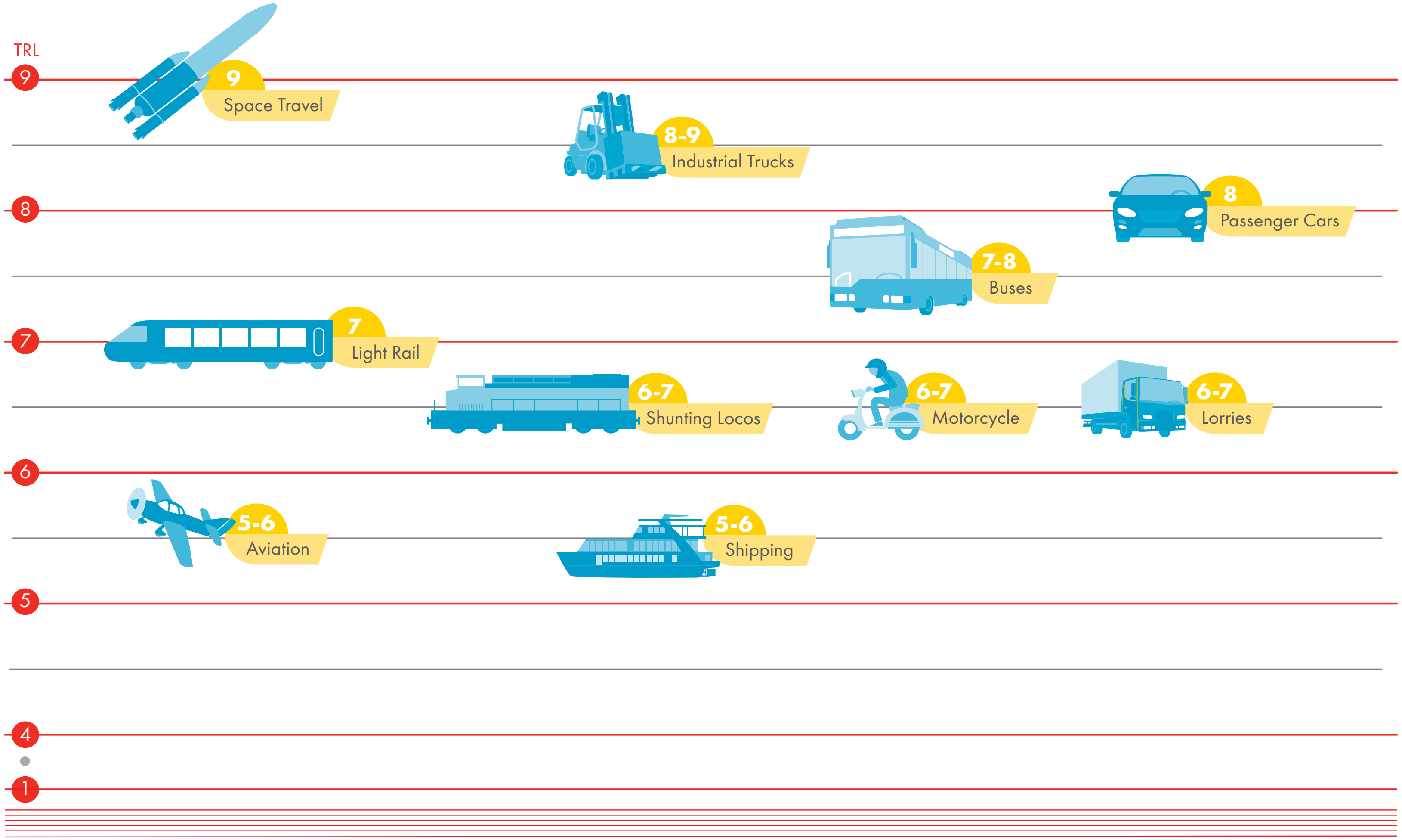


Applications in industries



Mobility applications

Broad range of options with different status (Technology Readiness Level)



Source: Wuppertal Institute, (Shell 2016)

Mobility applications in Germany

Fuel Cells used for mobility purposes in busses and trains

Regionalverkehr Köln GmbH

Recent developments:

- Regional Transport Companies (e.g. in Cologne and Wuppertal) ordered ordered 60 FC busses > Start of operation 2019

- First experience with fuel cell trains in northern part of Germany (substitute for diesel driven engines)

Erster Wasserstoffzug in Schleswig-Holstein

Premiere im Norden: Zwischen Neumünster und Kiel ist am Montag erstmals ein mit Wasserstoff angetriebener Zug unterwegs gewesen. Mit an Bord war Verkehrsminister Buchholz. (01.10.2018) **mehr**

Brennstoffzellenzug: Premiere mit hohen Erwartungen

Wassertropfen statt Ruß: Der weltweit erste mit Wasserstoff angetriebene Zug ist in Bremervörde zur Premierenfahrt gestartet. Heute folgt der Linienverkehr für "Coradia iLint". (17.09.2018) **mehr**

Source: WSW, RK, NDR, Alstom 2018

Mobility applications in Germany

Fuel Cell Vehicles still at the very beginning of market introduction

- Fuel cell car production clearly dominated by Asian companies
- In Germany mainly Mercedes (and BMW) are active, but still with low priority

Mercedes GLC F-Cell

Der GLC kombiniert zwei Energiespeicher: eine 90 PS starke Brennstoffzelle sowie einen Akku, der 100 kW beisteuert und das Auto zum Plug-in Hybriden macht. Batterieelektrisch sind nach NEFZ-Norm 50 Kilometer drin, 4,4 Kilogramm Wasserstoff bringen knapp 440 weitere Kilometer Reichweite. Beide schicken ihre Energie zu einem 211 PS starken Elektromotor, der die Hinterachse antreibt.


Foto: Mercedes-Benz

Mercedes GLC F-Cell.

- FC car fleet very small: 2019 only 392 FCEVs were on the road – in comparison to a total car fleet > 40 Mio. cars
- German government supports market introduction by up to 21,000 € per vehicle
- 60 hydrogen stations (+ 46 under construction/planned)

Source; Fischedick 2019

Stationary applications in Germany

Fuel Cells in buildings so far not in the focus – pilot and demonstration plants as well as first market offers

PROJECT DETAILS

Operation of 100 micro-cogeneration plants

PROJECT TARGET

Installation of various types of equipment in the field of micro-cogeneration (Stirling engine, Otto engine, fuel cell) as a comprehensive field test in Bottrop. Scientific support to optimise and support the introduction of energy-efficient gas-plus-application technologies. A secondary aim is the development and assessment of technology concepts which are adapted to the future application situation for the new building area but in particular also for the existing building stock and are highly efficient as regards primary energy.

InnovationCity Ruhr
Modellstadt Bottrop

Produktdetails zur Brennstoffzellenheizung

Details zur Vitovalor PT2 von Viessmann:

- Parallele Erzeugung von Strom und Wärme zur Minimierung der Stromkosten und zunehmende Unabhängigkeit vom Strompreis
- Integrierter Strom- und Gaszähler
- Brennstoffzelle: 750 Wel, 1 kWth; Gesamtwirkungsgrad 90 % (Hi); Elektrischer Wirkungsgrad 37 %
- Gas-Brennwertmodul: bis 18,9 kW oder 25,2 kW; (Trinkwasser bis 30 kW); Nutzungsgrad 98 % (Hs)
- Innovative Zukunftstechnologie
- Platzsparende Bauweise - benötigt nur 0,65 m² Aufstellfläche
- Leiser, komfortabler und intelligenter Betrieb
- Fernbedienung und Abruf von aktuellen Daten per App möglich

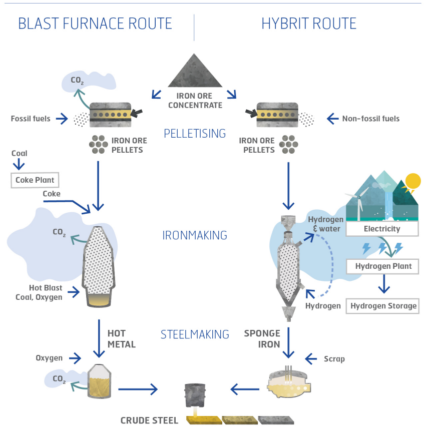
→ Weitere Details zur Vitovalor PT2 (/de/pk/heizung/brennstoffzellen-heizung/vitovalor.html)

- Pilot and demonstration program 100 small scale CHP plants (incl. fuel cells) in Innovation City Ruhr
- Market wins dynamic (based on financial support from government > 5,000 fuel cell systems have been ordered since 2016

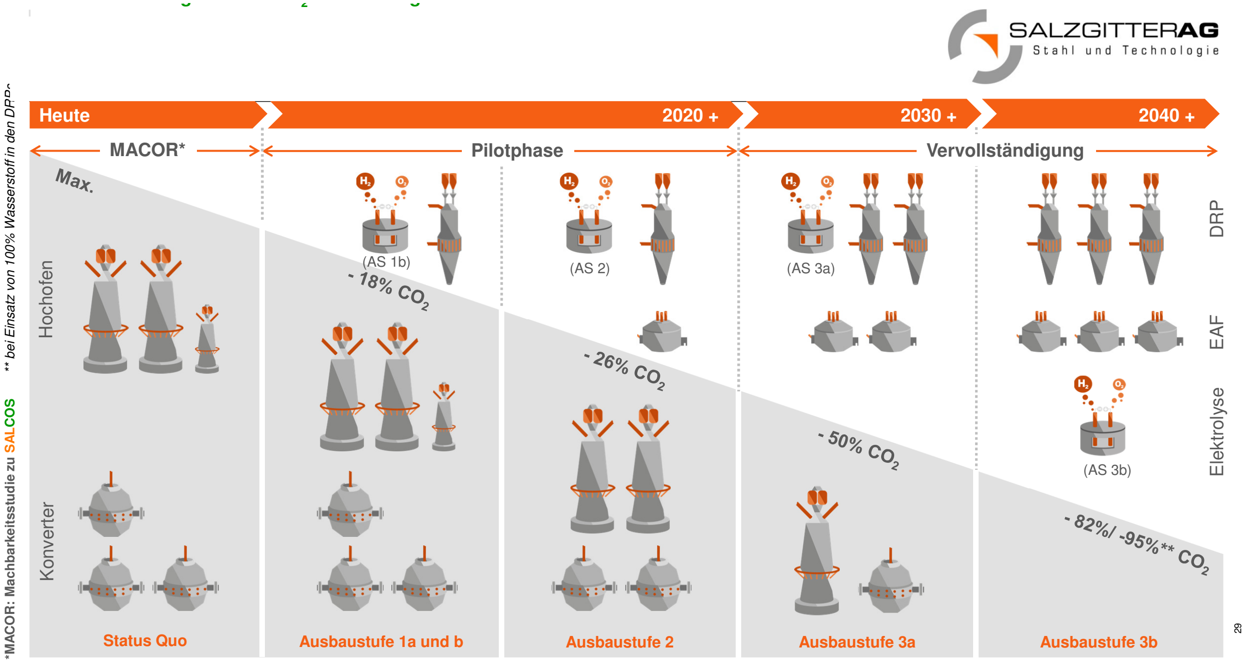
Source: Fischedick 2019

Applications in industry in Germany

Example: Steel making today and tomorrow (blast furnance -> hydrogen based steel making (direct reduction process)



- Concrete plans for step by step change of steel making process of major German steel companies (e.g. Thyssen Krupp Steel and Salzgitter AG)



Source: Fischedick 2019

Applications in industry in Germany

Example: Blending of fuels with hydrogen to cover EU CO_2-standards in refineries

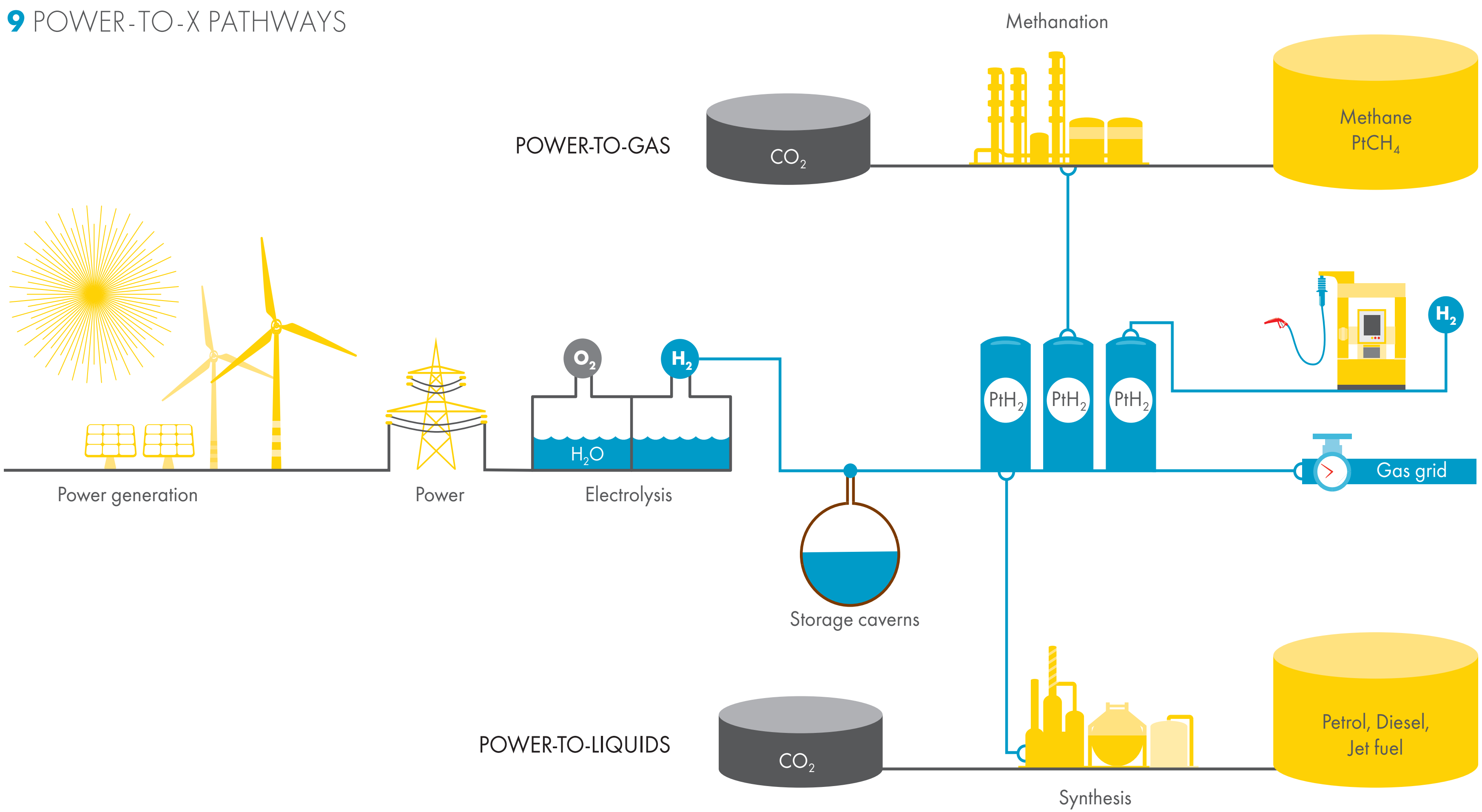
Refinery in Lingen (Emsland)

- BP and Uniper, together with the Fraunhofer Institute for Systems and Innovation Research ISI, submit project outline for the "Real-world laboratories energy transition" competition
- The planned project envisages the integration of renewable energy in the form of hydrogen into the transport sector
- Power-to-gas technology (PtG) in refinery processes (PtGtR) makes a positive contribution to the energy transition

Source: Fischedick 2019

Use of hydrogen from a systems perspective (focus PtX)

Hydrogen as basis for provision of synthetic gas/fuels or substitute for natural gas in the gas grid via Power to X-technologies



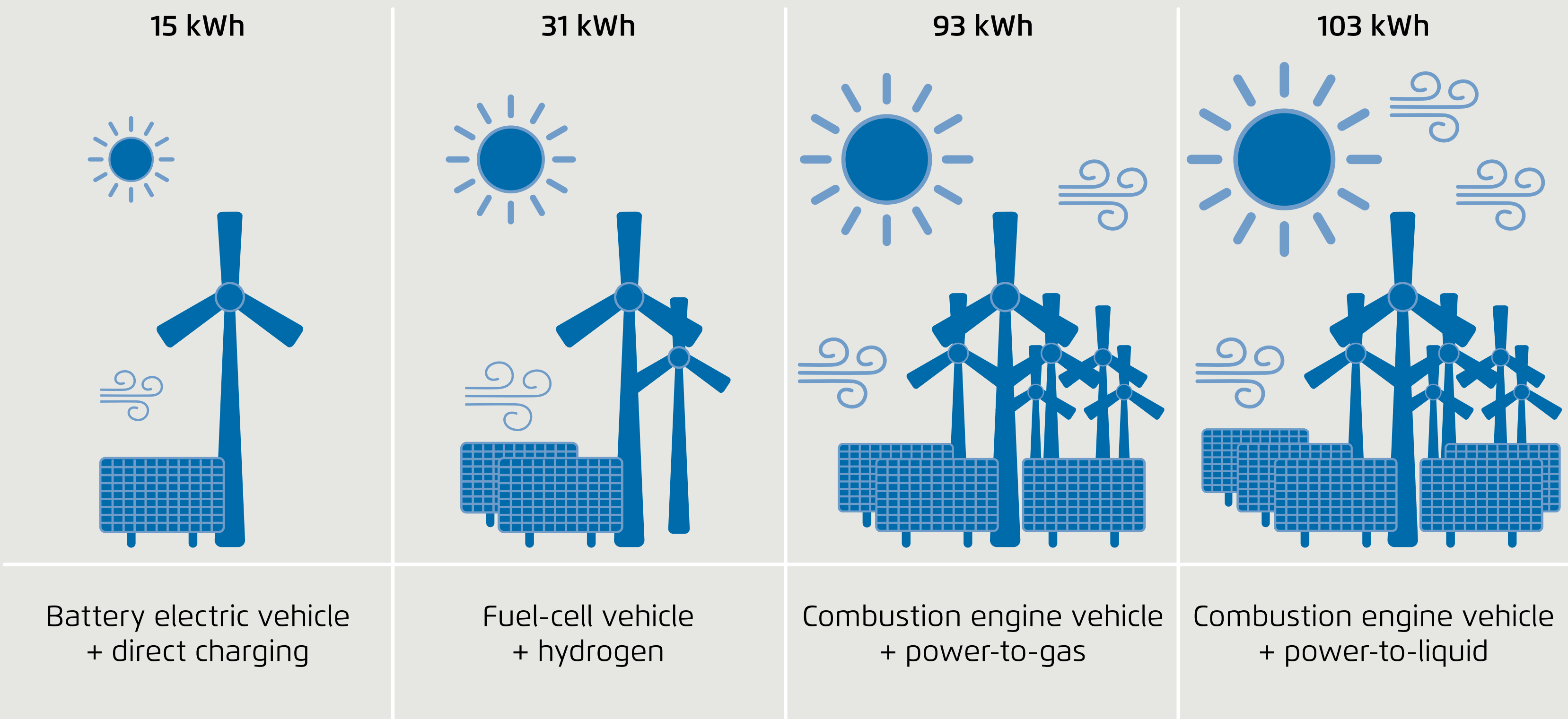
Source: Wuppertal Institute, (Shell 2016)

Hydrogen as an option for sector coupling (mobility)

Hydrogen based mobility is less efficient than electric vehicles but much better than synthetic (renewable based) fuels and needed for specific use

Amount of renewable energy required for various powertrain and fuel combinations (per 100 km)

Figure 6.1

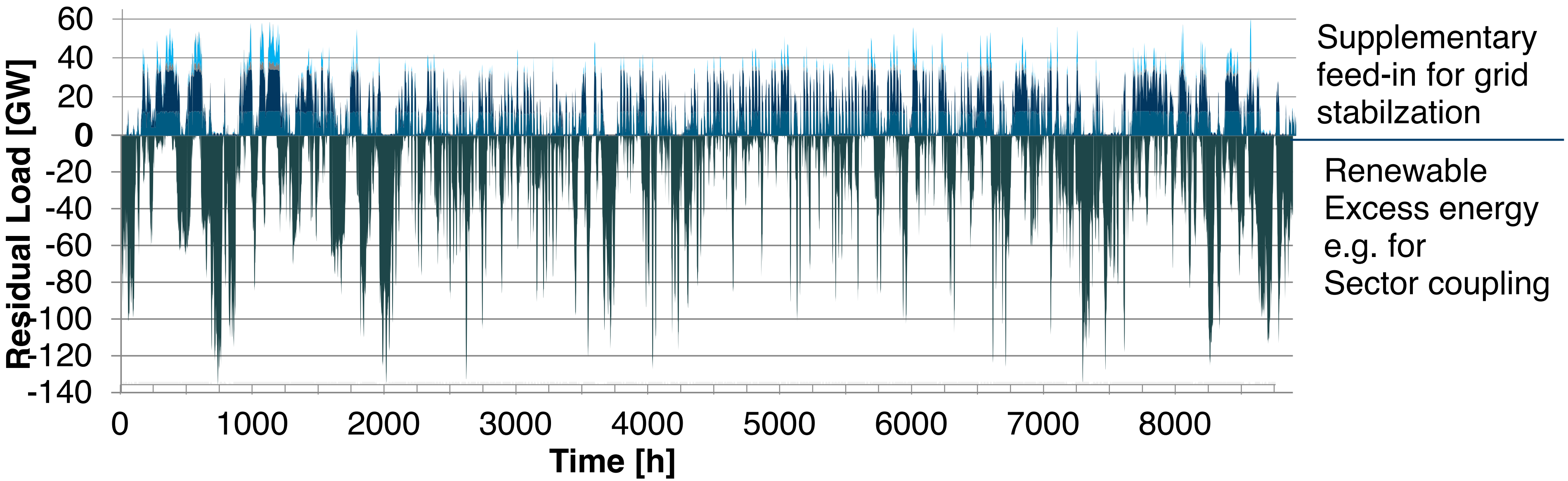


Source: Agora Energiewende 2017

Hydrogen as flexibility option for variable renewable power

Hydrogen can be stored, transported and provides multiple use cases

Growing fluctuations in the load curve over time (potential status in 2050 in Germany)



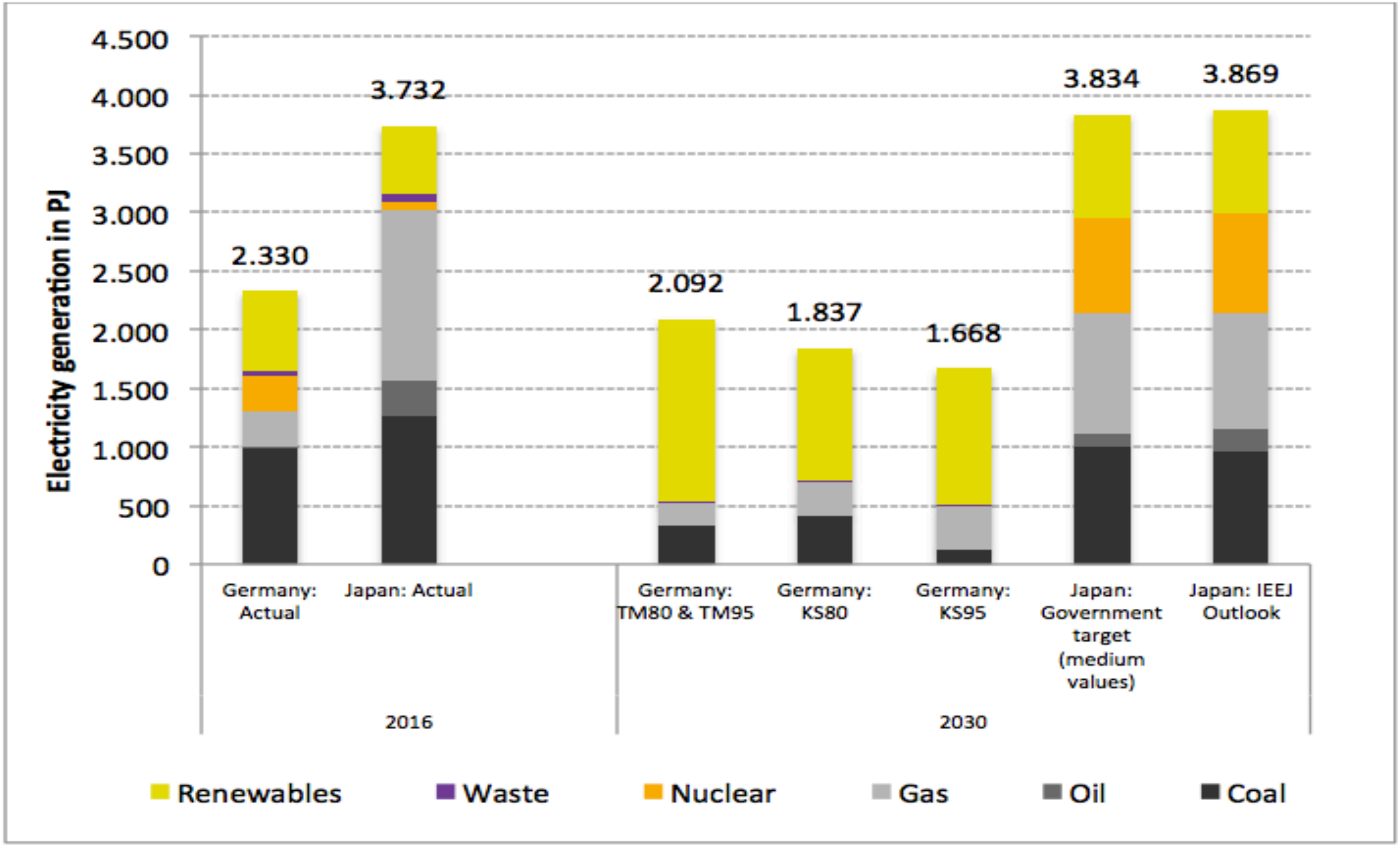
Back-up power production with gas turbines needed

- First fed with natural gas
- Later fed by hydrogen

Source: Stolten 2018

Electricity generation in Germany and Japan

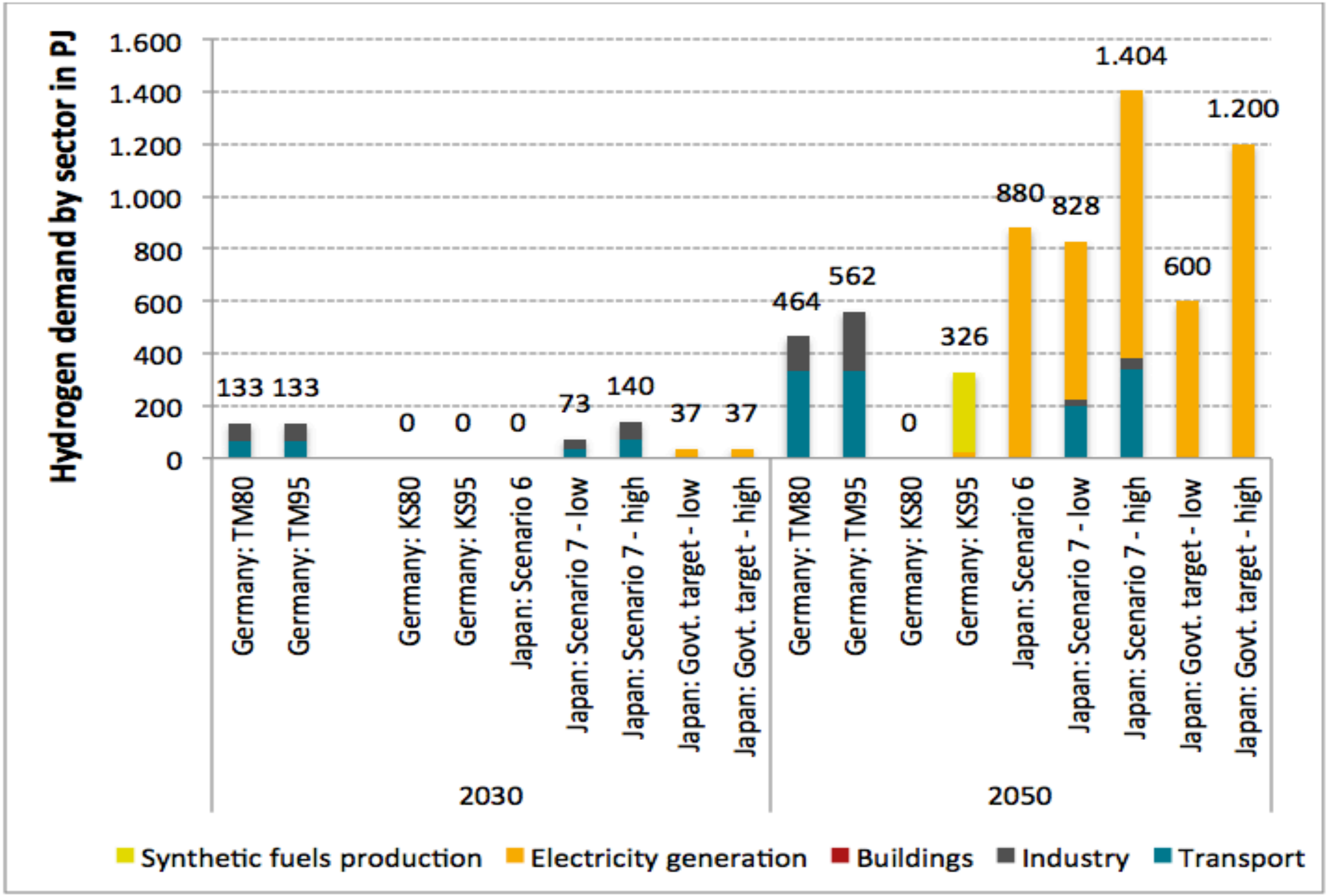
in 2016 and in 2030 for different scenarios



Source: adelphi et al. 2019: The role of clean hydrogen in the future energy systems of Japan and Germany, Draft August 2019

Use of hydrogen in Germany and Japan

in different scenarios in 2030 and 2050 (in PJ)

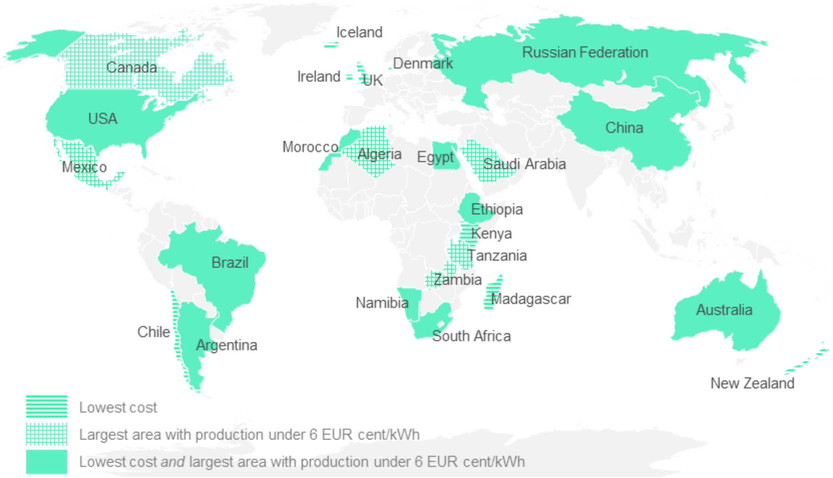


Source: adelphi et al. 2019: The role of clean hydrogen in the future energy systems of Japan and Germany, Draft August 2019, p. 70

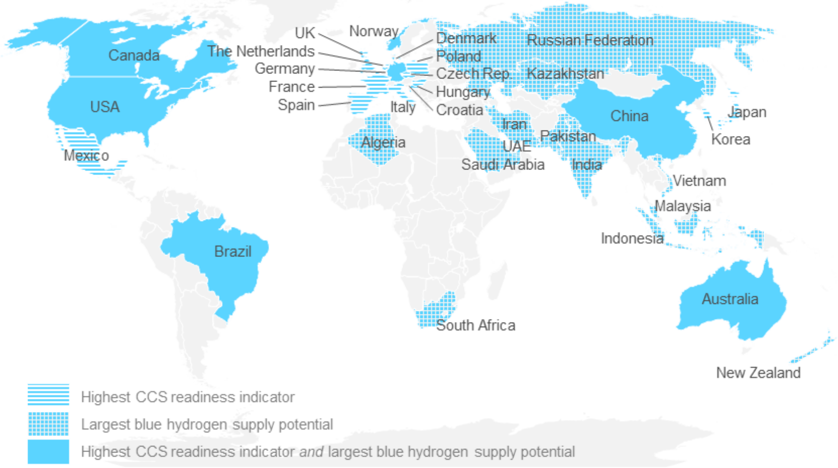
International supply chains: Potential partner countries

Country	Shared characteristics
Canada, US, Australia, China	Likely future blue and green hydrogen producers and technology providers
Saudi Arabia, Russia	Resource-rich countries with potential of both blue and green hydrogen production
Peru, Iceland, Ethiopia	Potential supplier of low-cost green hydrogen; no incentive to use hydrogen domestically, enabling green hydrogen export
Ireland, Chile, UK	Potential supplier of low-cost green hydrogen; a need to enhance energy self-sufficiency, thus likely facing competition between domestic consumption and export of green hydrogen
Netherlands, UK, Switzerland, France, Germany, Spain, Portugal, Israel, Italy, Belgium, Korea, Japan	Potential demand for low-carbon hydrogen; high-income, high dependence on primary energy imports, and likely future users with technology competence

Potential green hydrogen producers

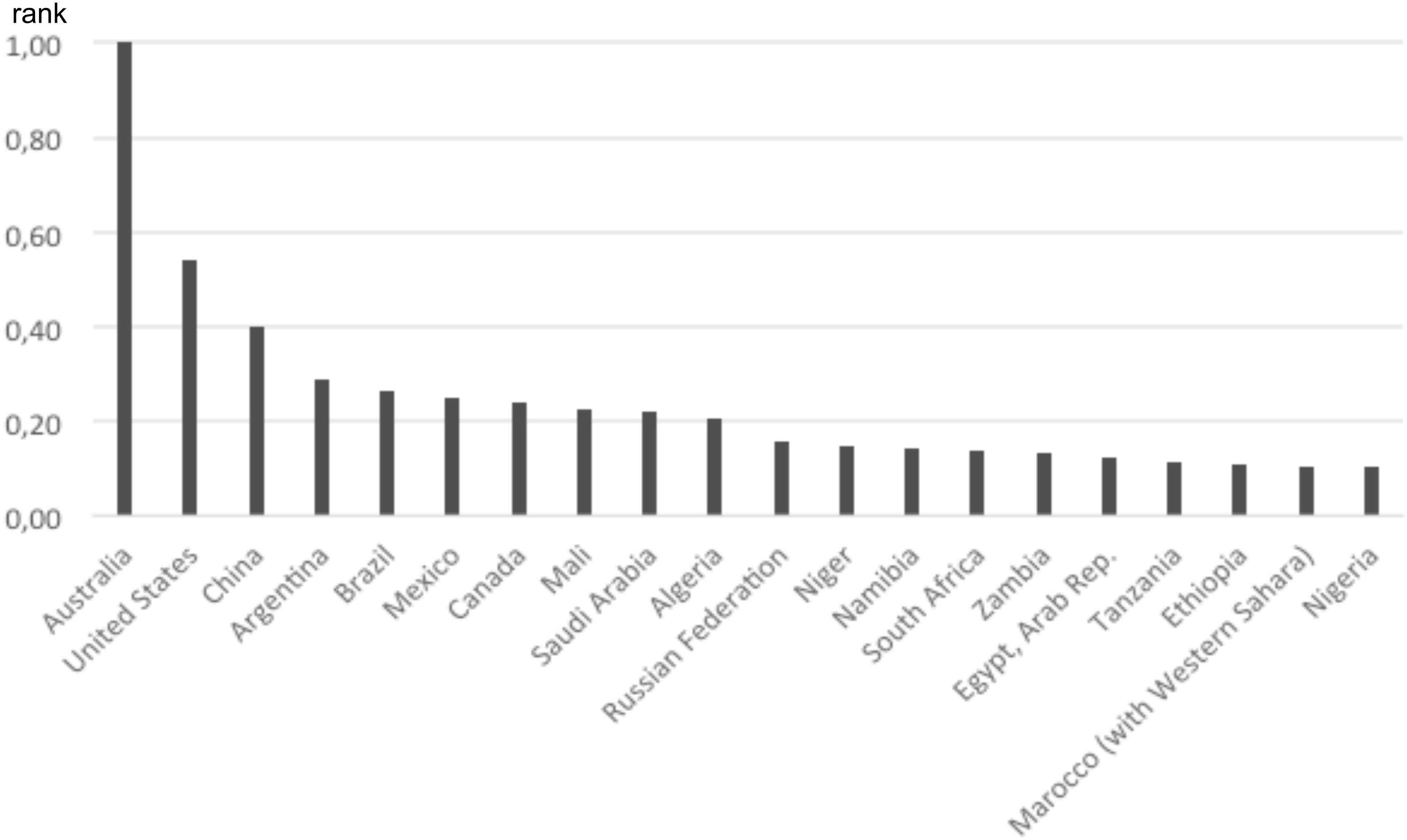


Potential blue hydrogen producers



Rank of 20 countries by land area

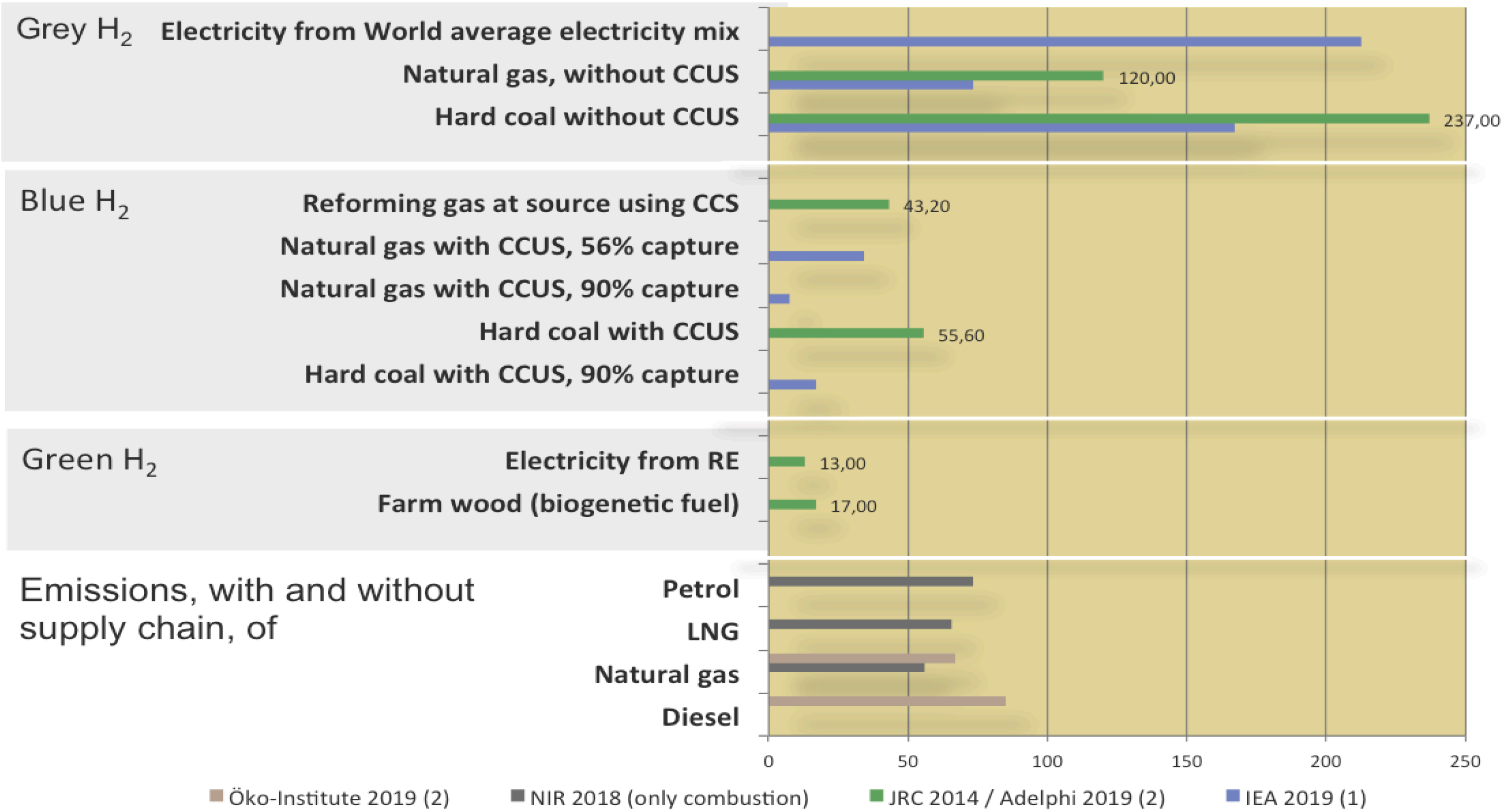
technically allowing green hydrogen production at 0.06 EUR/kWh



Source: adelphi et al. 2019: The role of clean hydrogen in the future energy systems of Japan and Germany, Draft August 2019, p. 89

GHG intensities of hydrogen supply chains (gCO_2 /MJ H_2)

and fossil fuels (1) production only; (2) whole supply chain



Source: adelphi et al. 2019: The role of clean hydrogen in the future energy systems of Japan and Germany, Draft August 2019, p. 69

Comparing GER and JAP: Preliminary findings
of the German-Japanese Energy Transition Council (GJETC)

- ✓ **Role of hydrogen**: In both GER and JAP, hydrogen is perceived to play a role in
- ➢ Deep decarbonisation
- ➢ Improving energy security
- ➢ Providing business opportunities (technology and knowledge export)

- ✓ **Timeline:** In both GER and JAP, hydrogen is envisioned to gain relevance <u>after 2030</u>.

- ✓ **Sector deployment might turn out differently for both countries**:
- ➢ In Japan, Hydrogen is envisioned to play the biggest role in power generation, followed by transport;
- ➢ In Germany, currently most of activities take place in the transport sector, and sector coupling via PtX

- ✓ **Hydrogen vs. synthetic fuels:**
- ➢ Japan is currently focusing more on hydrogen alone
- ➢ In Germany, the debate has been evolving around a combination of hydrogen and synthetic fuels

- ✓ **Sources of hydrogen:**
- ➢ Japan: focusing on import via hydrogen carriers (LH2, MCH, NH3, etc.) for blue and green hydrogen
- ➢ Germany: combining domestic green hydrogen production with imports of green hydrogen and synthetic fuels

Thank you very much for your attention