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Hydrogen RD&D Collaboration Opportunities: Germany

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Acknowledgments

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Contents

Executive summary: Germany

With large energy demands, extensive manufacturing capabilities, and technology leadership, Germany is a global leader in hydrogen. The 'Hydrogen RD&D Collaboration Opportunities: Germany' chapter aims to enhance country-to-country engagement by providing an overview of Germany's hydrogen priorities and ecosystem. This report also includes a publication and intellectual property (IP) scan, identifying the key stakeholders in Germany actively undertaking hydrogen RD&D, both at the early research and commercialisation stage.

Germany's hydrogen strategy

Germany's hydrogen strategy is driven by the need to decarbonise its economy, and to use hydrogen as an opportunity to support economic growth, new industries and job creation in many regions across Germany. Germany's strategy focuses on investing in the production of electrolysers to produce hydrogen from renewables (wind), importing hydrogen to meet its energy demand, developing a hydrogen gas pipeline network using new and old infrastructure, and using hydrogen across chemical, petrochemical and steel industries, as well as transportation modes that are difficult to electrify (heavy vehicles, trains, planes and ships).

Germany's targets and RD&D priorities

Germany's targets for 2030 are to grow its hydrogen consumption across the economy to 90-110TWh, and to produce 14TWh of hydrogen from renewable based electricity. By 2050, the targets for hydrogen consumption increase to roughly 380TWh of consumption (of which more than 80TWh will be needed for green steel, and roughly 22TWh needed to switch refinery and ammonia production to hydrogen). Germany plans to add an additional 5TWh of hydrogen production capacity before 2040. Based on Germany's National Energy and Climate Plans (NECP), the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) has published a range of hydrogen deployment scenarios for Germany in 2030, where hydrogen features across all end-uses, totalling a demand of 8,900-41,300 GWh/a.

To achieve these goals, Germany is investing in RD&D in the following areas.

Production
Electrolysis: polymer electrolyte membrane, alkaline, anion exchange membrane, and solid oxide
Fossil fuel conversion: methane pyrolysis, biological methods, photolysis

Storage and distribution
Compression and liquefaction: pressurised storage, pipelines
Chemical: ammonia, liquid organic hydrogen carriers, synthetic fuels
Other: tube trailers and tank lorries

Utilisation
Gas networks: pipelines
Transport: fuel cells, refuelling stations, fuel cell trains, fuel cell ships,
Electricity generation: ammonia turbines, hydrogen turbines, fuel cells
Industrial processes: steel processing, combustion, synthetic fuels, methanol production
Other: carbon recycling technology

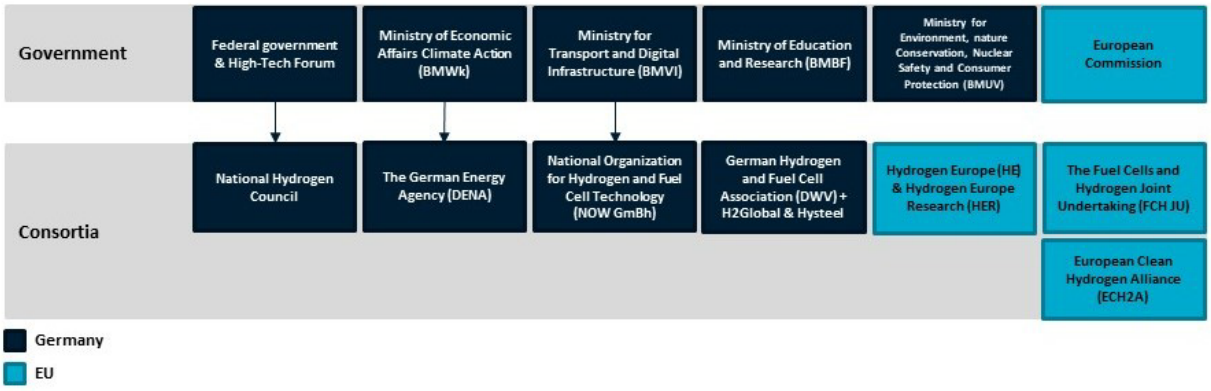
Cross-cutting
International standards
International supply chains studies
Testing
Modelling

Germany's domestic hydrogen landscape

The main government bodies in Germany involved in the development of a hydrogen economy are the Ministry of Economic Affairs and Energy (BMWK, previously BMWi), and the Ministry for Transport and Digital Infrastructure (BMDV). The BMWK published Germany's *National Hydrogen Strategy*, and both ministries are the primary funders of hydrogen and fuel cell RD&D programs across Germany, such as the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP and NIP2), and a number of mobility related programs. Funding also comes from Germany's Green Climate Fund, which supports basic research on hydrogen production from renewables, hydrogen energy technology research, and regulatory sandboxes for the energy transition. Additionally, the European Union funds hydrogen RD&D activity in Germany through its Horizon Europe program and other EU mechanisms.

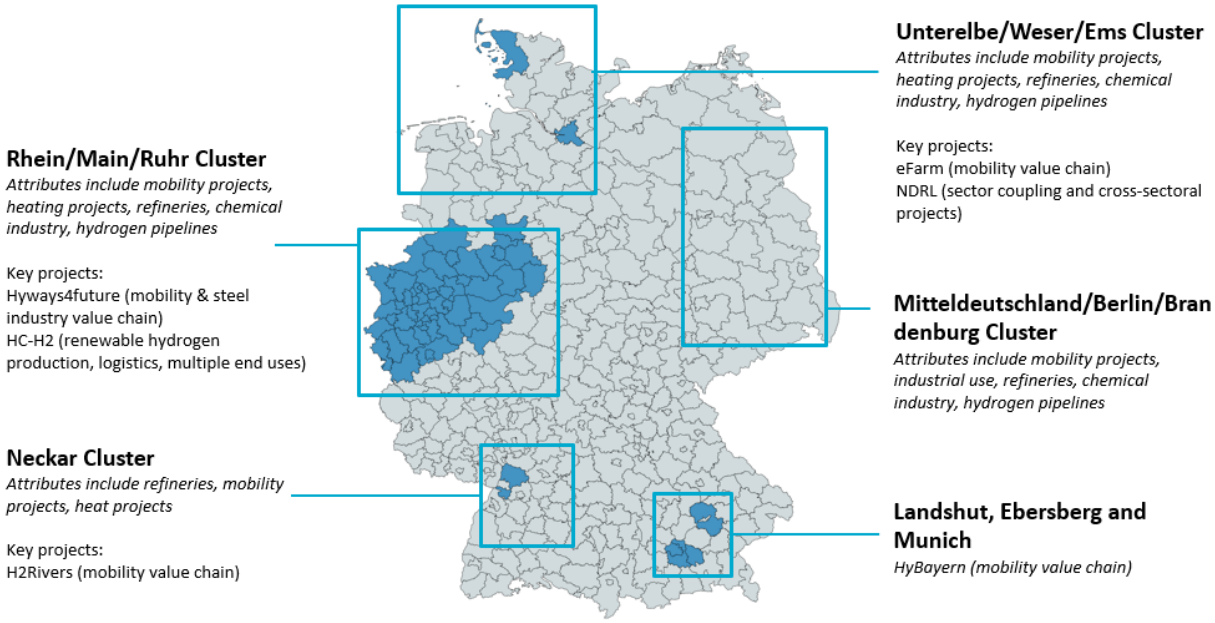
Germany has many highly active consortia and industry associations, namely the National Organisation for Hydrogen and Fuel Cell Technology (NOW GmbH), the German Hydrogen and Fuel Cell Association (DWV)and HySteel. German industry, academia and government stakeholders are also highly active in European level consortia.

Figure 1: Germany's hydrogen RD&D ecosystem



Industry and academia are collaborating to bring about hydrogen clusters (also known as hydrogen valleys, hubs or ecosystems). These clusters are hydrogen value chain demonstrations and pilot projects that cut across sector applications. The five major clusters of integrated hydrogen value chain activity in Germany are shown in Figure 2:

Figure 2: Germany's hydrogen clusters



Adapted from DENA, FCH JU and Mission Innovation (2021) Hydrogen Valleys

IP and publications scan

Several universities, public research institutions and private companies are highly active in early-stage hydrogen research and late-stage technology commercialisation. This is reflected in hydrogen research publication output and patent output data.

Table 1: Top organisations active in early-stage and late-stage hydrogen RD&D

Rank	Top organisations (Research publication output)	Top organisations (Hydrogen patent output)
1	Helmholtz Association	BMW
2	Max Planck Society	Robert Bosch
3	Karlsruhe Institute of Technology	Linde
4	RWTH Aachen University	Thyssenkrupp Industrial Solutions
5	University of Erlangen Nuremberg	Audi

International collaboration

In its *National Hydrogen Strategy*, Germany has signalled intent to collaborate on integrating hydrogen into existing energy trade partnerships and establishing new energy partnerships, technological collaboration, demonstrations and pilot projects in partner countries across the entire supply chain. Germany has several formalised relationships with other countries at the national level and has engaged in major supply chain demonstration projects with international partners.

Activity levels for hydrogen and net-zero initiatives is high. While effort has been made to capture major announcements and key information as at 18 August 2022, the content is intended to provide a starting point for informing international engagement, particularly when used in conjunction with other reports in the series, and is non-exhaustive.

1 Country analysis: Germany

1.1 Introduction

Alongside France, Germany is a major actor in both domestic and regional efforts to further hydrogen developments. Germany's is an established technological leader in clean energy and manufacturing and stands to benefit from sector coupling using hydrogen. With this considered, Germany is well-positioned to be both a major producer and importer of hydrogen. Germany's 2020 *National Hydrogen Strategy*[1] announced significant RD&D investments and several programs are currently under way to develop Germany's hydrogen economy. Germany's strategy encompasses all areas of the hydrogen value chain, citing domestic hydrogen production via electrolysers, infrastructure developments, and the decarbonisation of industrial sectors as key priorities. Further, Germany is engaging with several countries on developing international supply chains to supplement projected domestic demand through imports.

Germany's science, technology and innovation landscape is highly participative, and this is reflected in the hydrogen space. The National Hydrogen Council comprised of industry, research and civil society groups, is tasked with steering and advising the implementation of the national strategy. Similarly, implementation of RD&D by a diverse set of stakeholders. Through this, Germany has developed five major hydrogen clusters (also referred to as valleys, hubs or ecosystems). Germany is also a key contributor to the European Union's (EU) strategy and research, development and demonstration (RD&D)[2] programs and will play a central role in achieving regional emissions reductions and energy targets. This includes hydrogen value chain demonstrations and related infrastructure that cuts across national borders, paving the way to an interconnected European hydrogen economy.

The *Hydrogen RD&D Collaboration Opportunities: Germany* chapter presents an overview of the hydrogen RD&D landscape in Germany, starting from the national strategy level, down to activity in specific hydrogen technology areas.

1.2 Germany's hydrogen drivers, strategy and RD&D priorities

1.2.1 Germany's key drivers

In June 2020, the German Government released their *National Hydrogen Strategy.*[3] Though Germany has been active in hydrogen RD&D prior to the release of their strategy, the document outlined the nation's key hydrogen goals and priorities. The German *National Hydrogen Strategy* is primarily driven by achieving emissions reductions in line with the Paris Agreement and the economic growth opportunities presented by hydrogen.

- **Emissions reduction:** Germany's strategy emphasises their 2030 Climate Action Plan and the key role hydrogen will play in enhancing and completing their energy transition. Applications which are hard to electrify were especially identified as a key hydrogen opportunity in Germany's decarbonisation

[1] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany
https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

[2] As defined by the IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics, 2011

[3] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany
https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

efforts. Core objectives under this key driver include sector coupling of end use sectors and integration of renewables.

- **Economic growth:** In addition to recognising hydrogen's potential for decarbonisation, Germany also illustrates the economic benefits that can be derived from the technology. Hydrogen has been identified as an opportunity for economic growth and job creation in many regions in Germany. Furthermore, Germany states that hydrogen opens opportunities for fresh industrial policy and can help alleviate the economic consequences of the COVID-19 pandemic.

1.2.2 Germany's strategic hydrogen industry priorities

Germany has outlined several industry priorities in their national strategy. These are across hydrogen production, storage and distribution, utilisation, and cross-cutting applications: [4]

- **Production:** To help Germany's industrial sector to transition to hydrogen, Germany has proposed to provide funding for companies to make investments in electrolysers. To produce hydrogen from renewables, offshore wind energy has been identified as an attractive option. Investments will be made, and a framework has been developed by Germany to ensure investments pay off.
- **Imports:** Germany's strategy highlights that domestic production of hydrogen from renewables will not be sufficient to support a domestic hydrogen market. Much of Germany's hydrogen will need to be imported to meet local demand. Germany cites locations in Northern Europe, Baltic Sea, and Southern Europe as potential production sites, as well as systemic partnerships in other partner countries (particularly to co-launch investment and innovation campaigns and build new supply chains).
- **Infrastructure for transport and distribution:** Developing transport and distribution infrastructure and appropriately implementing it is a key priority for Germany. Germany plans to fully harness hydrogen technology, by building a dedicated hydrogen pipeline network (including assessing the conversion of natural gas pipelines). This will be achieved firstly by analysing current gas infrastructure to see whether conversion to hydrogen infrastructure is possible, and whether gas infrastructure, existing or upgraded, is compatible with hydrogen.
- **Utilisation**: Germany has identified hydrogen utilisation in the chemical, petrochemical and steel industries as key for industrial decarbonisation. In addition, Germany identified significant potential for hydrogen across hard-to-electrify transport modes (planes, ships, trains, buses, and heavy-duty and long-range vehicles. In light of the relatively mature electric vehicle market, hydrogen fuel cells for light and medium vehicles are less emphasised in the German strategy.

Germany's hydrogen targets

Germany's *National Hydrogen Strategy*[5] has set goals for hydrogen consumption, hydrogen production from renewables and generation capacity and imports (Table 2). Further, it should be noted that Germany is also contributing to the European Union (EU) and that the EU has also set targets for hydrogen.

On this note, Germany has welcomed the European Commission's package of legislative proposals on climate change collectively referred to as the 'Fit for 55' package which was passed in July 2021 as a response to the European Green Deal. The package proposes legislative changes and new policy measures

[4] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

[5] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

to achieve carbon neutrality by 2050 and to reduce net emissions by at least 55% by 2030, compared to 1990 levels.[6] The package further sets out various other EU-level targets by addressing sectoral regulations across the EU (See *Section 1.3.4 Other key hydrogen policies, regulation and legislation* for policies impacting EU members, including Germany). In the context of the European framework, Member States will be required to define their own target levels and policy approach to achieving these goals.[7] Germany has not released any related targets to date.

Table 2: Germany's hydrogen targets[8]

	Present	2030	Long term
Hydrogen Demand (Consumption)	55 TWh (1.65 million tons) p.a.	90-110 TWh	~380 TWh by 2050 (> 80TWh needed for GHG-neutral steel) (~22TWh needed to switch refinery & ammonia production to hydrogen)
Green Hydrogen Production	3.85 TWh electrolysis	14 TWh of hydrogen (from 20 TWh of renewable based electricity) 4,000 hours full-load operation water electrolyser, 70% average energy efficiency ratio	Additional 5 TWh of hydrogen no later than 2040
Generation capacity	-	5 GW (offshore and onshore)	(2040 Target) 10GW or more (offshore and onshore)
Imports	-	76-96 TWh	Imports will account for the majority of demand by 2050

Further, analysis by the EU and the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) calculated the potential opportunity for Hydrogen Energy Technology in the Germany economy, based on the National Energy & Climate Plans (NECP)[9] submitted. Results of the scenario analysis are outlined in Table 3.

[6] European Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[7] Herbert Smith Freehills (2021) Fit For 55 – EU Shifts Tactics For Proposed Energy Efficiency Directive. https://www.herbertsmithfreehills.com/insight/fit-for-55-eu-shifts-tactics-for-proposed-energy-efficiency-directive

[8] Adapted from BMWK (previously BMWi) (2020) The National Hydrogen Strategy. Federal Government of Germany; European Commission (2020) Draft Integrated national Energy and Climate Plan https://ec.europa.eu/energy/sites/default/files/documents/ec_courtesy_translation_de_necp.pdf

[9] European Commission (2021) National energy and climate plans (NECPs) https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en

Table 3: Opportunities for hydrogen in Germany by 2030[10]

	Conservative Scenario	Ambitious Scenario
Green Hydrogen Production	Electrolysers 2,970 MW and 8,940 GWh_{H2}/a	Electrolysers 13 680 MW and 41,200 GWh_{H2}/a
Industry	4,880 GWh/a	22,805 GWh/a
Refineries	810 GWh_{H2}/a	2,030 GWh_{H2}/a
Steel	1,870 kt/a	5,660 kt/a
Olefins	-	176.6 kt/a
Ammonia	-	140.9 kt_N/a
Methanol	-	59.1 kt/a
Aromatics	-	44.1 kt/a
Buildings	868 GWh/a	8,680 GWh/a
Micro-CHP* units	39,810 units	173,180 units
Commercial-Scale CHP* installations	60 installations	580 installations
Transport	3125 GWh/a	9,078 GWh/a
Refueling Stations	783	1,342
Trucks	32,430	64,770
Cars	477,000	954,000
Buses	760	1,510
Trains	110	340
Airplanes	227 GWh/a synthetic fuels	2,160 GWh/a synthetic fuels
Power	64 GWh/a (27 GWh/a electricity produced)	638 GWh/a (274 GWh/a electricity produced)

***CHP: Combined Heat and Power**

[10] Trinomics and Ludwig böklow systemtechnik (2020) Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans. Prepared for the FCH JU, EU.
https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Germany%20%28ID%209473039%29.pdf

1.2.3 Germany's hydrogen RD&D priorities

Table 4 illustrates Germany's RD&D priorities across the value chain. The table outlines sub-technology areas identified by Germany and the corresponding key RD&D priorities under that area. While priorities are outlined at a high level in Germany's *National Hydrogen Strategy,*[11] the Fraunhofer institute has provided a more detailed technology breakdown in *A Hydrogen Roadmap for Germany*[12].

Table 4: Germany's hydrogen RD&D priorities[13]

Supply chain area	Sub-technology areas	Germany's key RD&D priorities
Production	Electrolysis	Reduce cost to less than EUR 500 per kilowatt via RD&D, economies of scale, and automation. Optimising energy demand in flexible and dynamic operation. Energy and cost optimisation of peripheral system components such as power electronics (rectifiers and transformers) and gas processing (gas analysis, drying, compression). Development of quality assurance and certification for electrolysis components. **Alkaline:** Adapting cell materials to increase power density, efficiency, and service life for alkaline electrolysis. **PEM:** Alternative membrane materials in PEM electrolysis for increased operating temperatures. Non-precious metals catalysts (e.g. iridium, platinum), and developing suitable recycling. Increasing the size and service life of large-scale PEM stacks in the MW class. Development of competitive high-pressure electrolysers for decentralised applications. **Chlor-alkali:** Making facilities previously operated at base load more flexible in order to be amenable to renewable energies. **Other:** Germany is also interested in anion exchange membrane (AEM) and solid oxide electrolysis (SOE).[14]

[11] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

[12] Hebling C et al. (2019) Eine Wasserstoff-Roadmap für Deutschland [In German]. Fraunhofer. https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/2019-10_Fraunhofer_Wasserstoff-Roadmap_fuer_Deutschland.pdf

[13] Hebling C et al. (2019) A Hydrogen Roadmap for Germany. Executive Summary. Fraunhofer. https://www.fraunhofer.de/content/dam/zv/de/ueber-fraunhofer/wissenschaftspolitik/Positionen/2019-10-a-hydrogen-roadmap-for-germany.pdf; Hebling C et al. (2019) Eine Wasserstoff-Roadmap für Deutschland. Fraunhofer. https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/2019-10_Fraunhofer_Wasserstoff-Roadmap_fuer_Deutschland.pdf

[14] Consultation with in-country stakeholders

Supply chain area	Sub-technology areas	Germany's key RD&D priorities
	Fossil fuel conversion	Fossil fuel conversion may remain a RD&D priority for large industry stakeholders. However the German government is prioritising hydrogen produced from renewables over fossil fuel conversion with CCUS.[15] Key RD&D priorities in the area of fossil fuel conversion are: Methane pyrolysis for hydrogen production, for use in industry. Carbon dioxide (CO_2) feedstock provision by CCUS or DAC.[16]
Storage and distribution	Compression and liquefaction	Research, development, and demonstration of lower cost of transport technologies: Cryogenic storage, high pressure vessels, liquid hydrogen transport. Reducing the cost of high-pressure tanks made of carbon fibre (including improved manufacturing process for the carbon fibre).
	Hydrogen carriers	Lower the cost of hydrogen carriers: ammonia, methanol, liquid organic hydrogen carriers (LOHCs).
	Gas networks	Existing pipelines (conversion) and new pipelines.
Utilisation	Industry	Plants that can operate flexibly and cope with changes in feedstock and volume flow rates. Modularisation of processes for the refinery and chemical industry. Development of ammonia engines and turbines, and minimisation of nitrous oxide (NOx) emissions.
	Steel	Dynamic steel plants (reduction process and varying natural gas-hydrogen ratios, while improving steel product quality). Large scale-demonstration.
	Power generation	Pure hydrogen gas turbines: cost reduction, increased tolerance ranges, increased scale, and improved operational performance.
	Chemical and refinery	RD&D into the use of hydrogen produced from renewables in chemical recycling, to synthesise liquid fuel products from pyrolysis of plastics. Integration of pyrolysis and gasification processes with dynamic modes of operations, and improvements in catalysts. New production processes with optimized catalysts. Recovery, separation and capture of CO_2 in synthesis processes. **Power-to-liquid e-fuels (PtL):** Methanol synthesis (improved flexibility with respect to feedstock and flow rate, as well as coupling with electrolysis). Development of processes with closed carbon cycles. Analysis of the effects of changing feedstock on cross-industrial material flows. Large-scale demonstration of industry-related projects, integrating PtX processes into existing industrial infrastructure.

[15] Consultation with in-country stakeholders

[16] Consultation with in-country stakeholders

Supply chain area	Sub-technology areas	Germany's key RD&D priorities
	Mobility	Commercialisation of fuel cell buses, cars, trains and trucks by 2025. **Fuel Cells:** Reduce cost of fuel cells (for trucks and buses), increased lifespan (for trains and ships). Further development of fuel cell powertrains. **Materials:** Reduction of precious metals in fuel cells (platinum) while maintaining power density and efficiency. Increasing fuel cell lifetime by stabilising catalytic converters and catalytic converter carriers, and reducing sensitivity to contamination. Optimising coating of bipolar plates to improve longevity. Simplification of system components. Developing manufacturing processes for high-speed, high-throughput production, and quality assurance. Circular economy: reduce the cost of fuel cell materials while also reducing cost of recycling. **Other:** Scale-up of refuelling infrastructure, including heavy duty gas station networks. Hydrogen refuelling stations that can process cryogenic hydrogen, methanol, ammonia or LOHC.
Cross-cutting	International standards	Internationally harmonised and certified standards for hydrogen-based energy sources and chemicals.
	International supply chains	Research (e.g. feasibility studies into trade partnerships). System analysis on business models for global supply chains. Analysis of location, value chain technology options, and sustainability of potential supplier countries (including Australia). Concepts for market oriented production technologies (with regard to upscaling electrolyser production and the performance of individual electrolysis systems).
	Testing	Establishment of centres of excellence for system testing of components and support industrialisation, with respect to hydrogen storage, transport, and fuel cell production.
	Modelling	Economic assessments comparing alternative energy scenarios. Technoeconomic analysis. Energy system modelling.

1.3 Germany's hydrogen RD&D ecosystem

1.3.1 Public bodies and policy ecosystem

Overview of Germany's STI policy landscape

Germany is a global leader in science technology and innovation (STI) due to its strong system of finance infrastructure and institutions, support for university-based and enterprise-based research, and cooperation between the research sector and industry, innovation and start-ups. Germany's RD&D strategy, policy, and implementation are often conducted in a participatory manner via councils or consortia, with key leaders from government, industry, research, and civil society groups.

In continuation from the previous Merkel Chancellorship, Germany's current national STI policy framework and funding priorities are largely guided by the *High-Tech Strategy 2025*[17] (HTS), which has led to several other detailed strategies and roadmaps within the STI space, including Germany's *National Hydrogen Strategy.*[18] The latest *High-Tech Strategy* shifted STI funding from a "key technologies" approach to a "mission-based" approach. This improves horizontal coordination, involving broad range of stakeholders, and provides strong support not only for research and development (R&D), but also for social innovation, innovative business models, process innovation, and citizen participation.[19] Two of the six priority challenges articulated in the *High-Tech Strategy 2025*, "Sustainability, Climate Protection and Energy" and "Mobility" relate to hydrogen, particularly hydrogen produced from renewable technologies, broader energy system transformation in heating, industrial and transport sectors, and fuel cell technology.[20] Off the back of the High-Tech Strategy, several detailed strategies and roadmaps have been released.

The High-Tech Forum (HTF), chaired by the Federal Government and the Fraunhofer-Gesellschaft is the body tasked with advising the implementation of the HTS, by providing recommendations for Germany's research and innovation policy.[21] The HTF works with the Round Table of State Secretaries on the HTS to establish dialogue between ministries and other actors in the innovation system.[22] The Expert Commission on Research and Innovation (EFI) plays an evaluation and optimisation role to improve implementation.

Further, the HTS sets a goal to invest 3.5% of GDP (public and private) on R&D by 2025, one of the highest proportions globally.[23] This target was further reiterated in the 2021-2025 Coalition Agreement announced by Chancellor Scholz and government leaders in December 2021. The Coalition Agreement further described a mission-based approach taken toward the HTS and departmental research designed to improve horizontal coordination and provide support for R&D, innovation, and citizen participation.[24] Key areas of interest flagged under this document include: modern technologies to develop competitive and climate-neutral industries; climate, climate impacts, sustainability and adaption strategies; exploration of space and

[17] The Federal Government (2018) The High-Tech Strategy 2025. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/pdf/research-and-innovation-that-benefit-the-people.pdf?__blob=publicationFile&v=2

[18] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

[19] OECD (2021) STIP Compass Germany Overview. Viewed 26 July 2021 https://stip.oecd.org/stip/countries/Germany

[20] The Federal Government (2018) The High-Tech Strategy 2025. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/pdf/research-and-innovation-that-benefit-the-people.pdf?__blob=publicationFile&v=2

[21] European Commission (2018) Case Study Report: The German High-Tech Strategy (Germany). https://jiip.eu/mop/wp/wp-content/uploads/2018/09/DE_High-Tech-Strategy_Unger.pdf

[22] The Federal Government (2018) The High-Tech Strategy 2025. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/pdf/research-and-innovation-that-benefit-the-people.pdf?__blob=publicationFile&v=2

[23] The Federal Government (2018) The High-Tech Strategy 2025. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/pdf/research-and-innovation-that-benefit-the-people.pdf?__blob=publicationFile&v=2

[24] OECD (2021) STIP Compass Germany Overview. Viewed 26 July 2021 https://stip.oecd.org/stip/countries/Germany

oceans; and technological sovereignty and advancement.[25] To achieve this end, the Scholz leadership is set to establish the German Agency for Transfer and Innovation (DATI) to promote social and technological innovation by combining and expanding various funding schemes from different departments and making the funds available to universities, start-ups, small to medium enterprises (SMEs), and public organisations for the establishment of entrepreneurial infrastructure.[26]

Ministerial departments play a large role in the funding of STI research by defining key areas of interest and channelling a share of their federal funds into specific programs and federal institutions with R&D responsibilities. The leading ministries in this area are the Ministry of Education and Research (BMBF) and the Ministry of Economic Affairs and Climate Action (BMWK, previously BMWi).

Basic research is covered by public funding through Federal research institutions, research infrastructure, public academies and associations such as Max-Planck Gesellschaft and Helmholz Association (semi-privately funded and covers both basic and applied research). Public funding also covers applied research through universities, state-level institutions and the associations such as the Fraunhofer Gesselschaft (semi-privately funded). Applied research is also privately funded through industrial research associations (consisting of SMEs), R&D clusters, and larger industrial stakeholders and companies. The German Research Foundation (DFG) is a central, independent funding organisation in Germany and is financed by the federal government and states.[27] The DFG will fund the Academies of Science under the new leadership, and currently funds the Joint Initiative for Research and Innovation which is specifically aimed at non-university research.[28] The variety of research actors in Germany's system are illustrated in Figure 3.

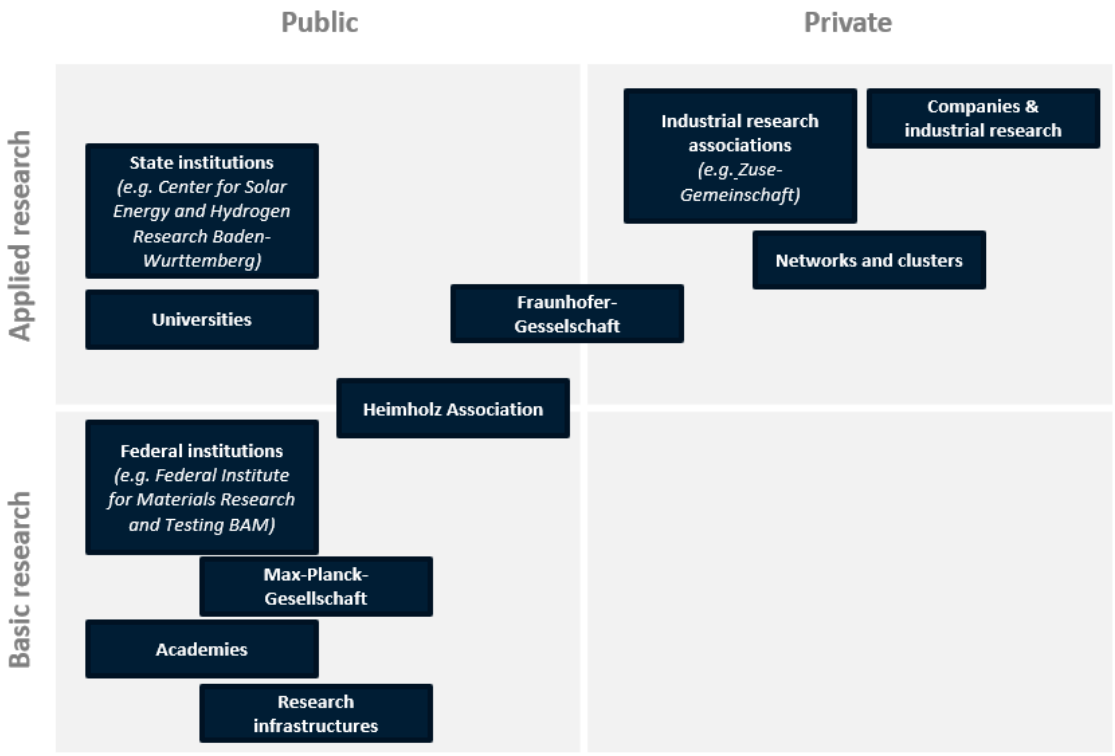
[25] The German Coalition (2021) Meht Fortschritt Wagen: BÜNDNIS FÜR FREIHEIT, GERECHTIGKEIT UND NACHHALTIGKEIT (Dare More Progress: Alliance for Freedom, Justice and Sustainability). https://www.fdp.de/sites/default/files/2021-11/Koalitionsvertrag2021-2025_0.pdf Unofficial English Translation Available at https://portal.ieu-monitoring.com/editorial/dare-more-progress-agreement-of-germanys-new-coalition-now-online?utm_source=ieu&utm_medium=web&utm_campaign=portal

[26] The German Coalition (2021) Meht Fortschritt Wagen: BÜNDNIS FÜR FREIHEIT, GERECHTIGKEIT UND NACHHALTIGKEIT (Dare More Progress: Alliance for Freedom, Justice and Sustainability). https://www.fdp.de/sites/default/files/2021-11/Koalitionsvertrag2021-2025_0.pdf

[27] The German Coalition (2021) Meht Fortschritt Wagen: BÜNDNIS FÜR FREIHEIT, GERECHTIGKEIT UND NACHHALTIGKEIT (Dare More Progress: Alliance for Freedom, Justice and Sustainability). https://www.fdp.de/sites/default/files/2021-11/Koalitionsvertrag2021-2025_0.pdf

[28] Helmholtz (n.d.) Joint Initiative for Research and Innovation. https://www.helmholtz.de/en/about-us/structure-and-governance/joint-initiative-for-innovation-and-research/

Figure 3: Landscape of R&D institution types in Germany[29]



Overview of Germany's hydrogen policy landscape

Germany's *National Hydrogen Strategy*, which came off the back of the High-Tech Strategy, was published by the BMWK in June 2020. The National Hydrogen Council (a body made up of members across industry, research and civil society groups) was commissioned by the cabinet in June 2020 to advise and support government with implementation of the *National Hydrogen Strategy* and has developed an 80-point action plan.

There are several ministries involved in the implementation of Germany's hydrogen RD&D priorities pertaining to Germany's hydrogen strategy and sustainability strategies. Under the Chancellorship, the three coalition parties have negotiated departments. Energy and climate policy has been moved into the former Ministry of Economy under the Green Party, in a bid to better integrate climate action and economic policy.[30] This ministry is responsible for renewable energies, the power sector, energy networks and the federal climate action law. The Green Party also maintains responsibility for the Environment Ministry (BMUV) which has within it the department of consumer affairs and responsibility for nature-based climate protection and resource policy in addition to providing hydrogen-based technology support.[31]

The Social Democratic Party (SPD) holds the Ministry of the Interior, Building and Community (BMI) and will implement approved approaches on climate-friendly construction and renewable heating systems. Moreover, the Free Democratic Party (FDP) has responsibility over the Finance Ministry (BMF) which supervises expenditure on climate policy and industrial policy, under which hydrogen falls. The FDP also

[29] Adapted from Federal Ministry of Education and Research (2021) Research Performing Organizations https://www.research-in-germany.org/en/research-landscape/research-organisations.html

[30] Kerstine Appunn (2021) The design of Germany's new govt: A climate "super ministry" for the Greens [Factsheet]. https://www.cleanenergywire.org/factsheets/design-germanys-new-govt-climate-super-ministry-greens

[31] Kerstine Appunn (2021) The design of Germany's new govt: A climate "super ministry" for the Greens [Factsheet]. https://www.cleanenergywire.org/factsheets/design-germanys-new-govt-climate-super-ministry-greens

holds the Ministry of Transport and Digital Infrastructure (BMVI) which is tasked with transition away from fossil-fuelled vehicles.[32]

Several consortia have been appointed to undertake implementation of RD&D programs. Further to this, actors in Germany's hydrogen space are also active at the supranational level, contributing to the EU's hydrogen strategy, EU hydrogen bodies, and EU hydrogen R&D programs (Figure 4) below illustrates the landscape of key actors in Germany's hydrogen RD&D and industry development. The general role of each of these actors and a description of their hydrogen activity is detailed in Table 5.

Figure 4: Summary of Germany's hydrogen RD&D policy ecosystem

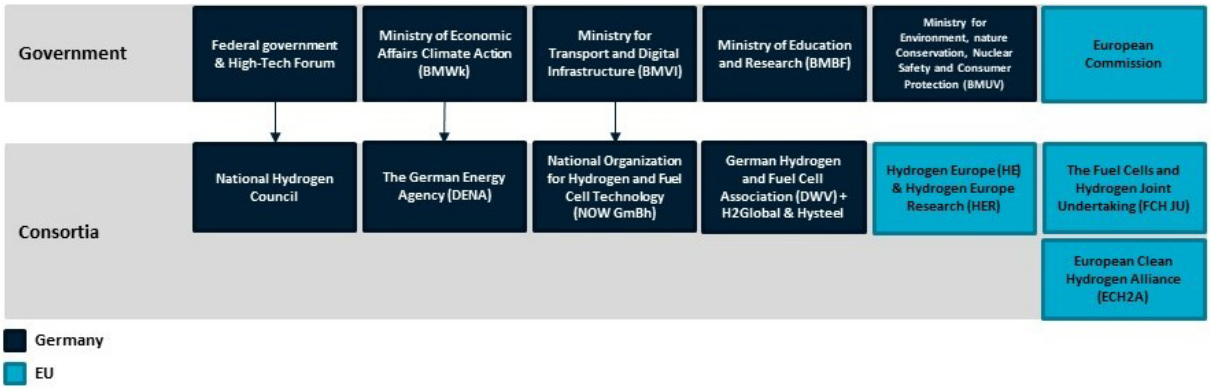


Table 5: Summary of key public bodies

Body	Role in RD&D ecosystem	Hydrogen initiatives
Federal Government & the High-Tech Forum	Coordinates activities across ministries, and actively involves science, industry and society in shaping Federal level research and innovation policy.[33] The High-Tech forum meets three times yearly to report from expert groups, and discuss Germany's overarching research and innovation policy issues.[34]	Developed the High-Tech Strategy 2025 setting the STI policy framework and priorities across the science system. Hydrogen is included in two key priority areas under this policy, "Sustainability, Climate Protection and Energy" and "Mobility".
NWR *National Hydrogen Council*	Off the back of the National Hydrogen Strategy the National Hydrogen Council was commissioned in June 2020 to advise and support government with implementation of the National Hydrogen strategy.	Published the hydrogen Action Plan 2021-2025, outlining 80 actions prioritised by urgency and timing to achieve a hydrogen economy.[35]

[32] Kerstine Appunn (2021) The design of Germany's new govt: A climate "super ministry" for the Greens [Factsheet]. https://www.cleanenergywire.org/factsheets/design-germanys-new-govt-climate-super-ministry-greens

[33] The Federal Government (2018) The High-Tech Strategy 2025. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/pdf/research-and-innovation-that-benefit-the-people.pdf?__blob=publicationFile&v=2

[34] European Commission (2018) Case Study Report: The German High-Tech Strategy (Germany). https://jiip.eu/mop/wp/wp-content/uploads/2018/09/DE_High-Tech-Strategy_Unger.pdf

[35] FuelCellsWorks (2021) Germany: National Hydrogen Council Hands Action Plan to the Federal Government. https://fuelcellsworks.com/news/germany-national-hydrogen-council-hands-action-plan-to-the-federal-government/>

Body	Role in RD&D ecosystem	Hydrogen initiatives
	The National Hydrogen Council is made up of 26 experts across business, science and civil society.	
BMWK (previously BMWi) *Ministry of Economic Affairs and Climate Action*	Ministry tasked with a legislative, administrative and coordination role in the areas of energy, industry, innovation, competition, SMEs and European policy. Priorities include supporting SMEs and start-ups, generating investment and cutting red tape, promoting digitisation, designing the energy transition, and developing of the European Economic and Monetary Union. [36]	Was the lead ministry in Germany's National Hydrogen Strategy. Provides funding for hydrogen development and commercialization via the "National Hydrogen and Fuel Cell Technology Innovation Programme" (NIP and NIP2) and funding for R&D via the Energy Research Programme.[37] Also provides funding for research consortia to establish 'practical laboratories' (Reallabore) for hydrogen and green energy research, and hydrogen projects H2Global and H2-Kompass.[38]
BMVI *Ministry for Transport and Digital Infrastructure*	This ministry has 69 subordinate agencies and is responsible for all federal activities related to mobility and information.[39]	The BMVI is investing EUR 23.5 million in hydrogen mobility as part of the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP and NIP2). In addition to this the BMVI is supporting RD&D and market activation programs in transport and mobility applications, namely Mobility and Fuel Cell Strategy (MKS) and the Renewable Fuels (RK).
BMBF *Ministry of Education and Research*	Ministry tasked with education policy and research policy. Provides funding for science and research institutions, universities and innovative SMEs. The BMBF also supports the Cluster4Future program (a flagship of the High-Tech Strategy 2025) funding regional clusters that tie into top level research.	The BMBF implements the national sustainability strategy (part of the national High-Tech Strategy). The BMBF's FONA (Research for Sustainability) Strategy focuses on the fields of hydrogen production from renewables, circular economy, climate change mitigation and bioeconomy.[40] This includes knowledge creation and translating this into practical application.

[36] BMWK (previously BMWi) (2022) Tasks and Structure of the Federal Ministry for Economic Affairs and Climate Action https://www.bmwi.de/Navigation/EN/Ministry/Tasks-and-Structure/tasks-and-structure.html

[37] BMWK (previously BMWi) (2021) Fuel cells and hydrogen. https://www.bmwi.de/Redaktion/EN/Artikel/Energy/research-priorities-fuel-cells-and-hydrogen.html

[38] Fuel Cells Bulletin (2021) Germany funds €100m per annum to test sustainable energy tech. https://www.magonlinelibrary.com/doi/epub/10.1016/S1464-2859%2819%2930351-7; George Heynes (2021) BMWi establishes 'H2Global Foundation' to provide new hydrogen funding platform, H2 View. https://www.h2-view.com/story/h2global-foundation-established-to-provide-new-hydrogen-funding-platform/; National Academy of Science and Engineering (n.d.) H2-Kompass – Signpost for Hydrogen. https://en.acatech.de/project/h2-kompass-signpost-for-hydrogen/

[39] BMVI (2021) About the Ministry. https://www.bmvi.de/EN/The-Ministry/Responsibilities-Structure/responsibilities-and-structure.html

[40] BMBF (2021) About FONA https://www.fona.de/en/about-fona/research-for-sustainable-development.php

Body	Role in RD&D ecosystem	Hydrogen initiatives
		The FONA program focuses on green innovations for urban and rural areas, and structurally weak regions. The Cluster4Future finalists in 2021 includes future hydrogen cluster covering production, storage and utilisation in the Aachen region and Rheinishce Revier. Partners are RWTH Aachen University and Forschungszentrum Jülich.[41]
BMUV *Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection*	Ministry tasked with the policy areas of environmental toxins and radiation, efficient use of raw materials, advancing climate action, consumer protection policy and promote conservation of biodiversity and natural habitats.[42] The ministry prepares legislation, funds R&D, supports innovation commercialisation, cooperates at national and international levels, and fosters public participation and acceptance.[43]	Launched the "Decarbonisation of Industries" support program aiming to reduce emissions from industrial processes, namely steel, cement, lime, chemicals and nonferrous metals (see *Section 1.4* for project details).[44] This includes investments such as production of green steel using hydrogen. The BMUV also launched the "Environmental Technologies Export Initiative" which includes providing opportunities for decentralised, off-grid hydrogen and fuel cell applications and creating market opportunities for these technologies in other countries.[45] The BMUV has also commissioned the International Power-to-X Hub in Berlin which is implemented by the GIZ GmbH (see *Section 1.5.3* for details).[46] More hydrogen-based technology support measures for energy intensive industries are in preparation by the BMUV.[47]

[41] Future Cluster Hydrogen (2021) Clusters4Future http://h2-cluster.de/

[42] BMUV (2021) Tasks and Structure. https://www.bmu.de/en/ministry/tasks-and-structure

[43] BMUV (2021) Tasks and Structure. https://www.bmu.de/en/ministry/tasks-and-structure

[44] Eurometal (2021) German Government Launches Promotion of Green Steel. https://eurometal.net/german-government-launches-promotion-of-green-steel/

[45] NOW GmbH (2021) New funding opportunities for hydrogen and fuel cell technologies within the Environmental Technologies Export Initiative: NOW GmbH supports BMU with project funding. https://www.now-gmbh.de/en/news/pressreleases/new-funding-opportunities-for-hydrogen-and-fuel-cell-technologies-within-the-environmental-technologies-export-initiative-now-gmbh-supports-bmu-with-project-funding/

[46] International PtX Hub Berlin (2022) About Us. https://ptx-hub.org/about-us/

[47] BMUV (2021) National Hydrogen Strategy. https://www.bmu.de/en/topics-1/climate-energy/climate/hydrogen-and-power-to-x/national-hydrogen-strategy

1.3.2 Hydrogen consortia

Table 6: Hydrogen consortia

Consortium	Description
NOW GmbH *National Organisation for Hydrogen and Fuel Cell Technology*	NOW was founded in 2008 and drives the implementation of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP and NIP2). (See *Section 1.3.3 Funding mechanisms* for more on the specific hydrogen initiatives under the National Innovation Programme).[48]
DWV *German Hydrogen and Fuel Cell Association* *(incl. H2Global Commission and HySteel)*	DWV is the leading body in Germany promoting hydrogen and fuel cell technology. The group is currently made up of 139 industry members. While operating independently from government, the group can receive funding for certain projects they conduct. The H2Global commission is a unit within the DWV and provides a platform to unite interests, knowledge and perspectives of economic actors and stakeholders of the future hydrogen industry. Is developing the H2Global funding program (Section *1.3.3 Funding mechanisms*).[49] HySteel commission is a unit within the DWV. It includes companies and organisations from business and science focused on jointly pursuing low-emission, hydrogen-based steel production.[50]
ECH2A *European Clean Hydrogen Alliance*	ECH2A is a European body bringing together industry, national and local public authorities, civil society and other stakeholders such as investors and R&D institutions. The members include several German industry groups such as BASF, BMW, Linde and Diamler.[51] The goal of the body is to assist in building a pipeline of investments to scale up the hydrogen value chain across Europe, in order to facilitate and implement the European hydrogen strategy.[52] The group meets in six roundtables each dedicated to a portion of the hydrogen value chain including production, transmission and distribution, industrial applications, mobility, energy sector and residential applications. [53]
FCH JU *The Fuel Cells and Hydrogen Joint Undertaking*	FCH JU is a public private partnership supporting hydrogen energy and fuel cell technologies across Europe, to accelerate commercialisation and diffusion. The program implements a fuel cell and hydrogen energy technology research and innovation program funded by Horizon 2020 (Europe's largest research and innovation program). The portfolio of projects includes hydrogen production from renewables, fuel cells for transport applications, minimising use of critical materials, storage and integration into

[48] European Commission (2021) NIP: National Innovation Programme for Hydrogen and Fuel Cell Technology. TRIMIS https://trimis.ec.europa.eu/programme/national-innovation-programme-hydrogen-and-fuel-cell-technology

[49] H2Global (2021) H2Global https://h2-global.de/#stiftung

[50] HySteel (2021) Hydrogen – For a Green Future of the Steel Industry https://dwv-hysteel.de/

[51] ECH2A (n.d.) List of the European Clean Hydrogen Alliance Members https://ec.europa.eu/docsroom/documents/42749/attachments/1/translations/en/renditions/native

[52] European Commission (2021) European Clean Hydrogen Alliance. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

[53] European Commission (2021) Roundtables of the European Clean Hydrogen Alliance. Internal Market, Industry, Entrepreneurship and SMEs . https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance/roundtables_en

Consortium	Description
	the energy system, and fuel cells for heat and electricity production.[54] The program also supports cross-cutting activities to support market uptake.[55]
HE *Hydrogen Europe* *&* **HER** *Hydrogen Europe Research*	HE is a European body bringing industry stakeholders, large companies and SMEs to develop and commercialise hydrogen and fuel cell technology. This association is made up of 2609+ companies and 27 associations from European nations including Germany.[56] Hydrogen Europe Research (HER) is the research counterpart of Hydrogen Europe and is made up of 91 universities and RTOs (research and technology organisations) from 26 countries (not limited to European member states), that are active within the European hydrogen and fuel cell sector.[57] The HER is a partner in the FCH JU.
DENA *The German Energy Agency*	DENA is a thinktank that engages with stakeholders domestically and internationally in areas of energy and climate protection. Nationally, DENA acts as independent advisor to corporate and political sectors and has specifically highlighted the area of battery and hydrogen-powered transport as a key area of advocacy.[58] While DENA's supervisory board is chaired by the state secretary at BMWK, it is a GmbH that operates as a private company.

1.3.3 Funding mechanisms

Overview of Germany's hydrogen public budget allocations

Germany's *National Hydrogen Strategy*[59] in 2020 announced funding for various hydrogen activities from research through to support for commercial hydrogen activities. These are distributed via various ministries and programs. At a high level, funding allocations are in Table 7 below.

Table 7: Germany's announced funding in the National Hydrogen Strategy 2020[60]

Description	Stage	Budget	Until
Conversion to fuel cells for automobiles, trains, coastal and inland water transportation vessels	Commercial	EUR 3.6 billion	2023
Development of hydrogen refuelling and recharging infrastructure	Commercial	EUR 3.4 billion	2023

[54] FCH JU (2020) Mission & Objectives https://www.fch.europa.eu/page/mission-objectives

[55] FCH JU (2021) Programme & Impact. https://www.fch.europa.eu/page/programme-impact

[56] Hydrogen Europe (2021) Home. <https://www.hydrogeneurope.eu>; Hydrogen Europe (2021) Hydrogen Europe: Industry https://www.hydrogeneurope.eu/about-us/115-2/

[57] Hydrogen Europe (2021) Hydrogen Europe Research https://www.hydrogeneurope.eu/about-us/research/

[58] DENA (n.d.) Alternative drive systems and fuels – foundations of the transport transition. https://www.dena.de/en/topics-projects/energy-efficiency/mobility/fuels-technologies/

[59] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

[60] Prepared by MGSSI based on data from the German Federal Ministry for Economic Affairs and Energy (Die Nationale Wasserstoffstrategie) and Research Center for Energy Economics (FfE), Munich. https://www.ffe.de/veroeffentlichungen/wie-gelangt-gruener-wasserstoff-zum-verbraucher-potenzielle-infrastruktur-fuer-wasserstoff-in-deutschland/; Mitsui & Co (2020) Germany's national Hydrogen Strategy. Mitsui & Co. Global Strategi Studies Institute Monthly Report, December 2020 https://www.mitsui.com/mgssi/en/report/detail/__icsFiles/afieldfile/2021/02/19/2012_fuhrmann_e.pdf

Description	Stage	Budget	Until
Hydrogen technology research (NIP2 and other programs)	RD&D	EUR 1.91 billion	2026
PtL facilities that convert electricity to liquid fuel	Commercial	EUR 1.1 billion	2023
Investment in new technologies and large-scale facilities to decarbonise industry	Commercial	EUR 1 billion	2023
Introduction of fuel cell heaters	Commercial	EUR 700 million	2024
Research and industrialization through the Living Labs (Reallabore) program	RD&D	EUR 600 million	2023
Research on practical application of fuel cell powered airplanes	RD&D	EUR 50 million	2024
Coronavirus economic stimulus package – launch of hydrogen market	Commercial	EUR 7 billion	Until funds deplete
Coronavirus economic stimulus package – international collaboration and cooperation in hydrogen	Cross-Cutting	EUR 2 billion	Until funds deplete

Germany's Public Funding for hydrogen RD&D

Funding for hydrogen RD&D in Germany is largely provided by the BMWK and the BMVI. Much of this is provided through national hydrogen programs such as the "National Hydrogen and Fuel Cell Technology Innovation Programme" (NIP and NIP2). The BMWK provides its funding for research and development via the Energy Research Programme. Many of the programs are coordinated by NOW on behalf of the German federal government. A summary of current domestic hydrogen RD&D funding programs through the NOW GmbH are detailed in Table 8 below.

Table 8: NOW GmbH programs for hydrogen RD&D[61]

Program	Support type	Providers	Budget & timeline	International eligibility to participate
National Hydrogen and Fuel Cell Technology Innovation Programme (NIP2) Launched in 2007, the NIP has been renewed for a second period (NIP2) from 2016 to 2026. The NIP is divided into three broad areas; transport and hydrogen infrastructure, stationary energy	Market activation R&D	BMVI, BMWK (funding support) BMUV, BMBF (advisory)	EUR 1.4 billion from 2016-2026[62]	No data.

[61] NOW GmbH (2021) Funding https://www.now-gmbh.de/en/funding/#funding-programmes-alternative-fuels; NOW GmbH (2020) Annual Report 2020 https://www.now-gmbh.de/wp-content/uploads/2021/05/NOW_Annual-Report-2020.pdf

[62] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

Program	Support type	Providers	Budget & timeline	International eligibility to participate
supply in households and industry, and special markets.				
Renewable Fuels (RK) Funding measure to provide technology-neutral support for renewable fuels (biofuels and electricity-based fuels). Funding comes from the Energy Climate Fund (EKF).	R&D Market Activation	BMVI	Total EUR 1.54 billion (2021-2024) EUR 640 million for development and demonstration EUR 900 million for commercial scale-up	No. Eligible applicants must be incorporated or registered in Germany.[63]
Export Initiative Environmental Technologies (EXI) Launched in 2016, for the promotion of export of green and sustainable infrastructure. Funding aimed at Germany tech companies in hydrogen and fuel cells that want to market their products internationally. Prioritises pilot/demonstration projects.	Pilot/Demonstration Market Activation	BMUV	No data	No. Eligible applicants must be incorporated or registered in Germany.[64]
Mobility and Fuels Strategy (MFS) Funding for energy transition in transport, current funding available for power systems in marine applications.	Market activation	BMVI	No data	No data
Alternative Drives in Rail Transport (ZUG) Funding directive to increase share of low-emission drive systems in rail transport. Provides support for companies and public bodies in procuring rail vehicles with low-emission drive systems including refuelling/charging infrastructure. This includes feasibility studies for alternative drive systems.	Market activation	BMVI	EUR 227 million 2021-2024	No data

[63] BMVI (2021) Funding Guideline for the Development of Renewable Fuels (in German). https://www.now-gmbh.de/wp-content/uploads/2021/08/20210825_FRL-Entwicklung_PT.pdf

[64] BMUV (2021) Richtlinie zur Förderung von Maßnahmen im Bereich des Exports von grüner und nachhaltiger (Umwelt-) Infrastruktur (in German). https://www.exportinitiative-umweltschutz.de/de/dateien/foerderung/antragsteller/20190607_handreichung-zur-richtlinie-der-exportinitiative-vom-21-05-19.pdf

Program	Support type	Providers	Budget & timeline	International eligibility to participate
Buses with Alternative Drives (BUS) Funding guidelines are still under development. Focus on procurement of buses with alternative drives (battery, battery overhead lines, fuel cells) and charging/refuelling infrastructure (batteries, hydrogen and methane).	Market activation	BMVI	EUR 1.25 billion 2021-2024	No data
Climate Friendly Commercial Vehicles (LKW) Focus on heavy road freight transport, replacing fleet with low- and zero-emission vehicles (batteries and fuel cells, charging/refuelling).	Feasibility/ R&D	BMVI	Total EUR 507.5 million 2021-2024 EUR 15 million per applicant, per calendar year.	No. Eligible applicants must be incorporated or registered in Germany.[65]

In addition to the programs above, the German government also contributes to hydrogen RD&D funding through the BMWK and BMWF, shown below in Table 9. BMWK funding is often awarded via the Energy Research Programme which is funded through Germany's Green Climate Fund. Also highlighted below are funding arrangements that are open to Australian applicants.

Table 9: Hydrogen RD&D funding provided through key government ministries[66]

Department	Description	Budget (2020-2023)	International eligibility to participate
BMWK	**Basic research on hydrogen production from renewables.** Part of the Energy Research Programme.	EUR 310 million	Applicants must be registered in the European Economic Area.[67]
BMWK	**Hydrogen energy technology research.** Part of the Energy Research Programme.	EUR 200 million	Applicants must be registered in the European Economic Area.
BMWK	**'Regulatory Sandboxes' for the energy transition (includes hydrogen).** Part of the Energy Research Programme.	EUR 600 million	Applicants must be registered in the European Economic Area.

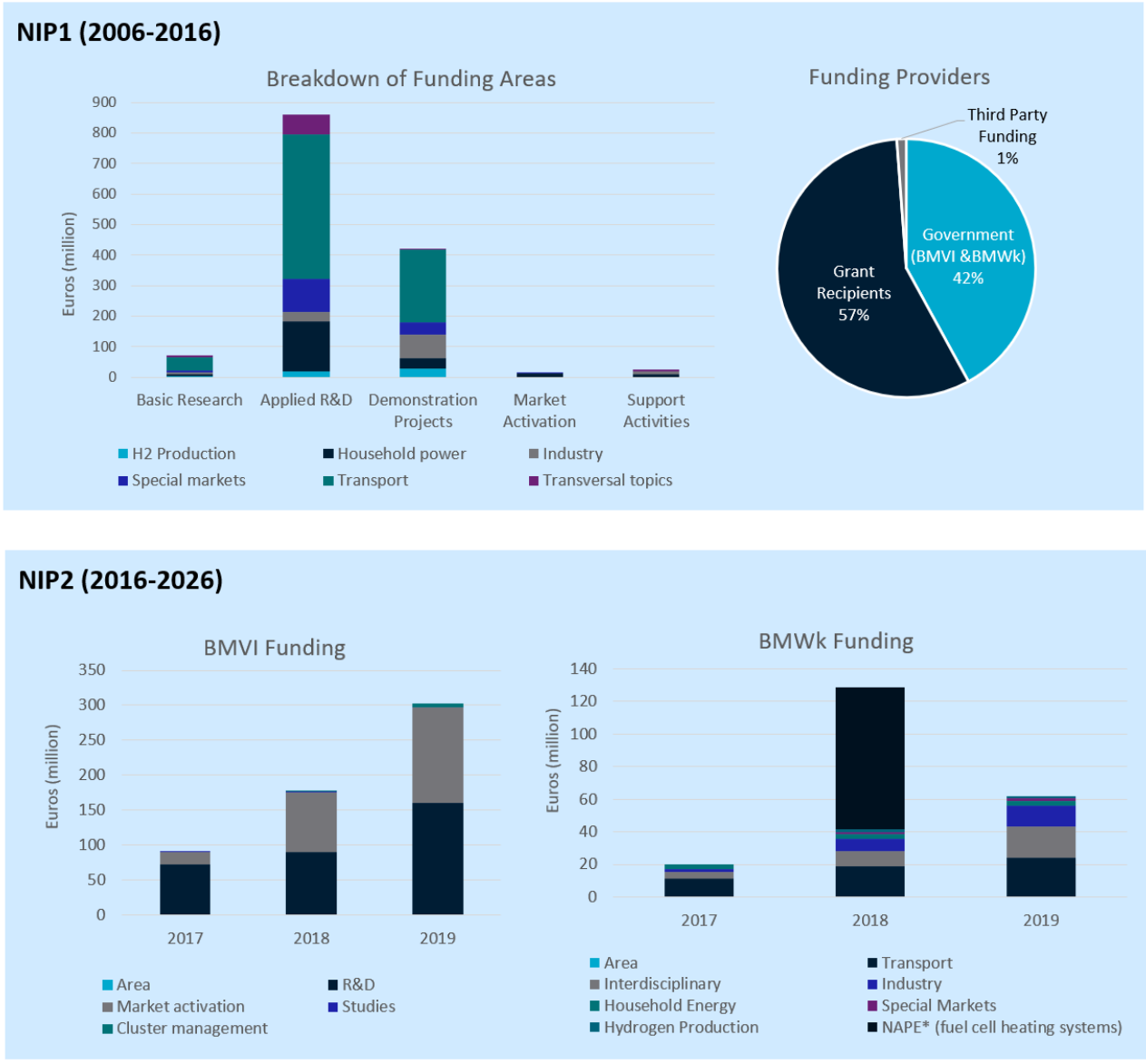
[65] Federal Office for Goods Transport (BAG) (2021) FAQ on the 1st funding call August 12th 2021. https://www.bag.bund.de/SharedDocs/Downloads/DE/Foerderprogramme/KsNI/KsNI_FAQ_Foedergegenstand_KsN.pdf?__blob=publicationFile&v=5

[66] BMWK (previously BMWi) (2020) The National Hydrogen Strategy. The Federal Government, Germany https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6

[67] BMWK (previously BMWi) (2018) Innovations for the Energy Transition: 7th Energy Research Programme. https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/7th-energy-research-programme-of-the-federal-government.pdf?__blob=publicationFile&v=5

A breakdown of the NIP1 and NIP2 illustrate the trends and specific areas of focus for hydrogen RD&D, and market activation funding in Germany (Figure 5). BMVI funding towards the NIP are more targeted towards demonstration activity, whereas BMWK funding is more targeted towards R&D.[68] Note that the increased BMWK funding in 2018 came from NAPE (National Action Plan on Energy Efficiency) for the purchase of fuel cell heating systems for private customers.

Figure 5: NIP Funding Trends



***NAPE (National Action Plan on Energy Efficiency) contributed funds for the purchase of fuel cell heating systems for private customers.**
Adapted from McKinsey & Co (2017) Evaluation of the National Innovation Program Hydrogen and Fuel Cell Technology Phase 1 (2006 bis 2016) Prepared for BMVI and BMWk, Coordinated by NOW; NOW (2017) Annual Report 2017; NOW (2018) Annual Report 2018; NOW (2019) Annual Report 2019

[68] Bonhoff K (2010) NIP – The German National Innovation Programme Hydrogen and Fuel Cell Technology. 18th World Hydrogen Energy Converence 2010 https://juser.fz-juelich.de/record/135833/files/78_11.pdf

Funding for international hydrogen RD&D

Table 10 outlines funding arrangements that are available to international organisations and individuals, with a highlight on arrangements with Australian access.

Table 10: Funding for international hydrogen RD&D

Body	Funding mechanism	International eligibility to participate
BMBF	**International Future Labs** funding are centres of excellence at German universities or research institutions that collaborate with international researchers. Funding is provided to teams from at least two partner countries to work on identified research areas within hydrogen produced from renewables. In general, projects will be funded for a maximum amount of EUR 5 million for up to 36 months.[69]	Yes. Must partner with German researchers.
BMBF	**HyGate** is a German-Australian hydrogen incubator for applied research and pilot projects. Funding is provided by BMBF (EUR 50 million) and Australia (AUD 50 million).[70]	Yes.
BMWK	**H2Global** is a mechanism to support a competitive and market-driven expansion of hydrogen produced from renewables and its derivatives. It operates via establishing partnerships between Germany and foreign countries in which hydrogen can be efficiently produced and a supply chain established.[71]	Yes. EUR 900 million
BMBF & BMWK	As of October 2021, the BMBF and BMWK have released a funding guideline to support international hydrogen projects in countries that have energy partnerships with Germany (22 to date). EUR 350 million is available until the end of 2024 across commercial and research sectors, with joint projects also eligible. Commercial projects may receive up to EUR 15 million, with scientific and research institutions receiving up to EUR 5 million.[72]	Yes.

European Union funding for hydrogen RD&D

German hydrogen RD&D activities are also funded through various EU R&D and innovation framework programs. The EU Hydrogen Strategy has outlined several European funding mechanisms that it plans to use for the development of a hydrogen economy in Europe.

[69] BMBF (2021) Announcement of regulations for funding International Future Labs for Green Hydrogen https://www.bmbf.de/SharedDocs/Publikationen/bekanntmachungen/files_anncmnt-bmbf_future_labs_green_hydrogen-pdf.pdf?__blob=publicationFile&v=3#:~:text=The%20term%20%22International%20Future%20Lab,with%20the%20best%20minds%20worldwide.

[70] BMBF (2021) Signing of a letter of intent to establish a German-Australian hydrogen accord https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/06/20210613-unterzeichnung-einer-absichtserklaerung-zur-gruendung-einer-deutsch-australischen-wasserstoffallianz.html.

[71] BMWK (previously BMWi)

[72] BMWi (2021) Overview of the core elements of the funding guideline to support the international establishment of generating installations for green hydrogen [Joint Press Release]. Viewed at https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/10/20211004-overview-of-the-core-elements-of-the-funding-guideline-to-support-the-international-establishment-of-generating-installations-for-green-hydrogen.html

Table 11: EU funding mechanisms for hydrogen RD&D

EU funding mechanisms	International eligibility to participate
Horizon Europe:[73] This EU program is the largest EU research and innovation program, providing EUR 95.5 billion for the period 2021-2027. Hydrogen projects falling under this program are led by the FCH JU. This program is part of a series of EU funding for RD&D; preceding this program was the Horizon 2020 program which ran from 2014-2020, and the FP7 program which ran from 2002-2013. New elements under the Horizon Europe program include the launch of the European Innovation Council, an open science policy, and 5 new mission areas.	Yes, so long as a bilateral science and technology agreement with the EU is maintained.[74] Collaboration criteria are likely to be stringent and likely subject to co-contribution.
IPCEI (Important Projects of Common European Interest): Funding in the EU is also allocated to projects that fall under the IPCEI. IPCEI is an instrument enabling funding for research and innovation that meet European strategic interests and that have spillover effects across country borders in the EU. These projects also involve private financing by the beneficiaries of the program funding. Funding is allocated for hydrogen with respect to addressing market failures for large cross-border integrated projects for hydrogen and hydrogen-derived fuels that significantly contribute to achieving climate goals.[75] Funding for projects is provided jointly by partner country governments as well as private funding.	Applicants must be members of the European Union.[76]
InvestEU: This is part of Next Generation EU, a new recovery instrument which supplied increased funding in response of the COVID-19 pandemic, and mobilises more than EUR 372 billion in private and public funds. This fund targets commercially viable projects (demonstration or deployment stage) in areas where there are market failures or investment gaps. Allocation of funds falls into four key windows: sustainable infrastructure; research, innovation and digitisation; SMEs; and social investments and skills. Hydrogen activities will be supported within the sustainable infrastructure window, targeting all areas of the hydrogen value chain.[77]	Yes, it is possible for international financial institutions to become implementing partners. Also, can participate by means of a decision pursuant to an international agreement.[78]

[73] European Commission (n.d.) Horizon Europe. https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

[74] IRN-FACES (2021) Funding Opportunities https://faces-irn.cnrs.fr/funding-opportunities/; European Commission Horizon Europe. https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/europe-world/international-cooperation_en#Horizon-Europe

[75] EU Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[76] European Commission (2021) Communication from the Commission: Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest. Document 52021XC1230(02). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2021.528.01.0010.01.ENG&toc=OJ%3AC%3A2021%3A528%3ATOC

[77] European Commission (2021) Invest EU. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/hydrogen/funding-guide/investeu_en

[78] Official Journal of the European Union (2021) Regulation (EU) 2021/523 of the European Parliament and of the Council of 24 March 2021 establishing the InvestEU Programme and amending Regulation (EU) 2015/1017. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R0523&qid=1617090511360

EU funding mechanisms	International eligibility to participate
ERDF (European Regional Development Fund), Cohesion Fund & REACT-EU:[79] This instrument serves to reduce disparities between EU regions by funding capital-intensive environmental and transport investments through grants. 30-37% of funds under the ERDF are prioritised to support a transition to a climate neutral economy. Programs under this initiative will run their course to 2023, however new programs are currently being drafted for the period 2021-2027. For 2021-2027 the ERDF will comprise EUR 226 billion and the Cohesion fund EUR 48 billion.[80] The REACT-EU provides an additional EUR 50.6 billion stimulus package to the program for 2021 and 2022 to support a green recovery. This funding mechanism supports hydrogen activities in the areas of renewable and low-carbon hydrogen,[81] technology transfer, public-private partnerships, and pilot projects. Hydrogen project eligibility are assessed on a case-by-case basis.	Applicants must be members of the European Union.[82] For the Cohesion Fund, access is limited to select EU Member States.[83]
Connecting Europe Facility Energy & Connecting Europe Facility Transport: These mechanisms seek to accelerate investments in transport, energy and digital infrastructure networks. This fund is dedicated to demonstration, studies, and co-financing of energy infrastructure with priority given to cross-border linkages and systems.[84] This facility has been allocated EUR 30 billion for the period of 2021-2027.[85] This mechanism can be used to fund hydrogen infrastructure, repurposing gas networks, carbon capture projects and hydrogen refuelling stations.[86]	Applicants must be members of the European Union, however, there may be potential for foreign participants as a third party entity via subcontracts.[87]

EU funding trends for hydrogen RD&D from 2008 to 2018 are depicted in This illustrates the increases in hydrogen RD&D funding each year stemming from two programs, the FP7 and the subsequent Horizon2020. Note that this has now been superseded by a new program, Horizon Europe.

[79] European Commission (2021) European Regional Development Fund, Cohesion fund and REACT-EU. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/hydrogen/funding-guide/european-regional-development-cohesion-fund-react-eu_en

[80] European Commission (2021) Commission welcomes the adoption of €373 billion Cohesion policy legislative package 2021-2027. Newsroom. https://ec.europa.eu/regional_policy/en/newsroom/news/2021/06/25-06-2021-commission-welcomes-the-adoption-of-eur373-billion-cohesion-policy-legislative-package-2021-2027

[81] The European Union Commission defines low-carbon hydrogen as hydrogen produced from fossil fuels with CCS, and electricity-based hydrogen with significantly reduced full life-cycle GHG emissions compared to existing hydrogen production. The term 'clean hydrogen' is used for hydrogen produced from renewables (but not fossil fuels with CCS). Fossil fuels with CCS is defined as 'blue' hydrogen. Hydrogen from pyrolysis of natural gas with pure carbon as a side product is defined as 'turquoise' hydrogen; European Parliament (2021) EU hydrogen policy: Hydrogen as an energy carrier for a climate-neutral economy https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf

[82] European Commission (2020) REGULATION (EU) 2020/2221 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Document 32020R2221. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R2221&qid=1611824380100; European Commission (n.d.) European Regional Development Fund. https://ec.europa.eu/regional_policy/en/funding/erdf/

[83] European Commission (n.d.) Cohesion Fund. https://ec.europa.eu/regional_policy/index.cfm/en/funding/cohesion-fund/

[84] European Commission (2021) Connecting Europe Facility – Energy. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/hydrogen/funding-guide/connecting-europe-facility-energy_en

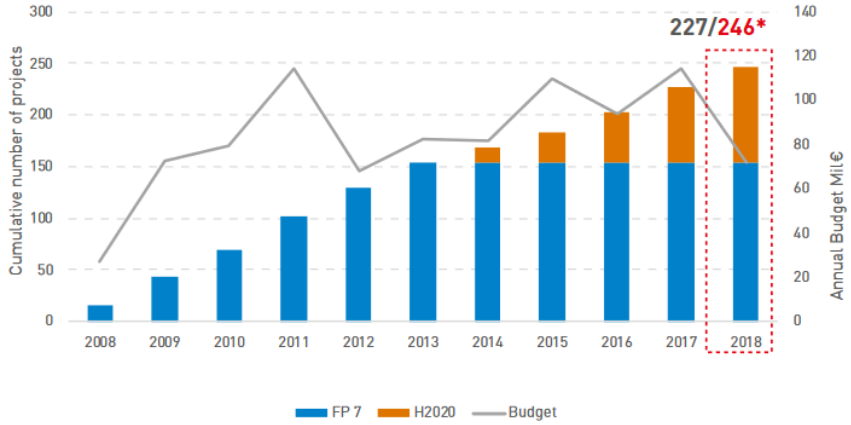
[85] European Parliament. (2021) €30 billion for infrastructure projects connecting EU regions. News. https://www.europarl.europa.eu/news/en/press-room/20210701IPR07504/EU30-billion-for-infrastructure-projects-connecting-eu-regions

[86] EU Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[87] European Commission (2018) Guidelines on the Eligibility of Costs under the Connecting Europe Facility. https://ec.europa.eu/inea/sites/default/files/wifi4eu/model_grant_agreement/version_for_applicants_and_beneficiaries-final-_v01.pdf

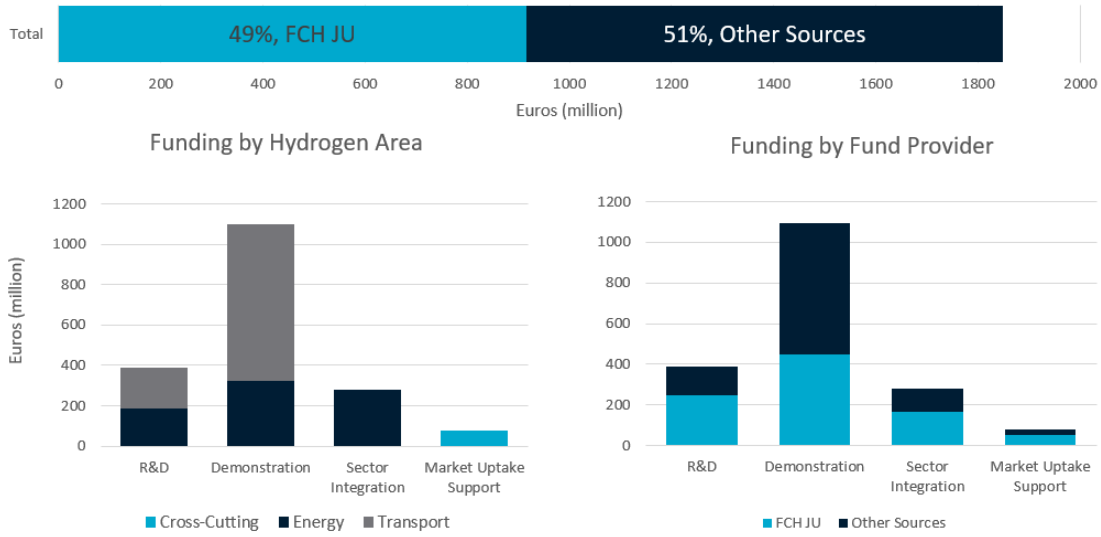
Figure 6 below. This illustrates the increases in hydrogen RD&D funding each year stemming from two programs, the FP7 and the subsequent Horizon2020. Note that this has now been superseded by a new program, Horizon Europe.

Figure 6: EU trends for hydrogen RD&D funding (2008-2018)[88]



* Projects included in the Programme Review 2018 covering calls 2008-2017/Projects signed on 1/9/2019.

Figure 7: Hydrogen funding breakdown (2008-2018)[88]



EU Hydrogen Funding Compass

The various European Funding mechanisms include grants, subsidies, financing, technical assistance and procurement. The funding available for different RD&D life cycle stages can be found on the EU Hydrogen Public Funding Compass:

- https://ec.europa.eu/growth/industry/hydrogen/funding-guide/eu-programmes-funds_en

[88] Derived from FCH JU (2020) Programme Review Report 2019. European Commission
https://www.fch.europa.eu/sites/default/files/documents/Programme%20Review%20Report%202019.pdf

1.3.4 Other key hydrogen policies, regulation and legislation

In addition to the governance, strategy and funding mechanisms for hydrogen RD&D programs, Germany has several key policies, regulations and laws to incentivise and regulate the commercial uptake of hydrogen technologies. Notable policies and regulations are outlined below.

Policies and Legislation

At the national level:

A comprehensive legal and regulatory framework which regulates the hydrogen value chain in Germany is yet to be developed. The German Government has noted that reform is necessary to incentivise hydrogen innovation and commercial scaleup.[89] Notable reforms and policy proposals are as follows:

- An R&D tax scheme was introduced in Germany in 2020 to benefit SMEs and support cooperation between business and research institutions. This is meant to complement project-oriented R&D support.
- The National Strategic Framework for the Expansion of Alternative Fuel Infrastructures (implementing Directive 2014/94/EU) includes goals and measures to build charging infrastructure for electric vehicles, natural gas supply infrastructure (compressed and liquefied natural gas) and hydrogen supply infrastructure for fuel cell vehicles.[90]
- In June 2021, the German parliament passed amendments to the *German Energy Economy Act* which regulates hydrogen distribution networks.[91] Broadly speaking, the purpose of the amendments is to provide network operators with the necessary regulatory certainty to scale up hydrogen infrastructure until European guidelines are established. At a high-level, the Act defines a 'hydrogen network' and outlines various provisions and obligations relevant to network operators, including:
  - Prohibiting the ownership or construction of hydrogen production, storage and distribution facilities by network operators;
  - Unbundling the hydrogen system from the natural gas network;
  - Requiring network operators to provide third-party access to the hydrogen network; and
  - The creation of a cost-based tariff network aligned with current frameworks.
- In December 2020, the *Germany Renewable Energies Act* and the *German CHP Act 2020* were amended to facilitate the domestic scaleup of the hydrogen economy.[92] Notable amendments include:
  - Creation of independent regulations for hydrogen storage and distribution systems. These regulations are less strict than regulations for existing electricity grids and natural gas networks, but align with EU requirements (see EU level policies and legislation); and
  - Reducing the electricity surcharge for hydrogen producers by 85%. This means the electricity levy for energy intensive undertakings which produce neutral hydrogen will be limited to 15%.

[89] CMS (2021) Hydrogen Law and Regulation in Germany. https://cms.law/en/int/expert-guides/cms-expert-guide-to-hydrogen/germany

[90] Trinomics and Ludwig böklow systemtechnik (2020) Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans. Prepared for the FCH JU, EU.

[91] Clifford Chance (2021) Focus on hydrogen: Germany implements first pure hydrogen midstream regulation and introduces definition for green hydrogen https://www.cliffordchance.com/content/dam/cliffordchance/briefings/2021/06/focus-on-hydrogen-germany-implements-first-pure-hydrogen-midstream-regulation.pdf

[92] Herbert Smith Freehills (2021) Legal briefings: Hydrogen in Germany https://www.herbertsmithfreehills.com/latest-thinking/hydrogen-in-germany

Hydrogen from renewables producers will be exempt from any electricity levy, provided eligibility criteria are satisfied.[93]

- The German Government is looking to streamline tendering processes for hydrogen production from renewables to incentivise industry decarbonisation.[94]
- The Government has implemented a Contracts for Difference (CfD) market platform to help industry, particularly in the steel, cement and chemical sectors, decarbonise and transition to low-carbon technologies.[95] Launched in 2021, the H2Global Foundation is a new funding mechanism made up of 16 companies. It was initially designed by the Society for International Cooperation (GIZ) and is being further developed by the DWV. The foundation provides businesses with secure backing for planning and investment activities to incentivise market scale-up for hydrogen production from renewables and Power-to-X products – predominately through its funding arm, H2Global.[96] Here, the Hydrogen Intermediary Network Company (HINT.CO) will tender Hydrogen Purchase and Service Agreements (HPAs and HSAs) and bridge the gap with a CfD subsidy. The funding sets an incentive to ramp up the hydrogen market by making up the difference between purchase price of derivatives and domestic sales price.[97] The BMWK will provide EUR 900 million to H2Global to support this process.[98] This aligns with a similar pilot scheme to be developed by the EU (see EU level policies and legislation).

At the EU level:[99]

- In 2019 the FCH JU laid out the *Hydrogen Roadmap Europe*[100] and in 2020 the European Commission laid out a European *Hydrogen Strategy*.[101] As a large economic player in the region Germany is a contributor to the drafting and the achievement of these strategies.
- All member states publish Integrated National Energy and Climate Plans (NEPCs), modelled on Germany's Energy Concept, outlining plans to cut carbon and GHG emissions by 2030 and 2050.
- The European Union will develop and introduce a comprehensive terminology and European-wide criteria for the certification of renewable and low-carbon hydrogen (by June 2021).
- The European Union will endeavour to develop a pilot scheme for a 'Carbon Contracts for Difference' program, to support the production of low-carbon and circular steel, and basic chemicals. As discussed

[93] Herbert Smith Freehills (2021) Legal briefings: Hydrogen in Germany https://www.herbertsmithfreehills.com/latest-thinking/hydrogen-in-germany

[94] Herbert Smith Freehills (2021) Legal briefings: Hydrogen in Germany https://www.herbertsmithfreehills.com/latest-thinking/hydrogen-in-germany

[95] Reuters (2021) German government proposed green funding tool to help industry cut CO_2 https://www.reuters.com/business/sustainable-business/exclusive-german-government-proposes-green-funding-tool-help-industry-cut-co2-2021-04-30/>

[96] BMWK (previously BMWi) (2021) Minister Altmaier: "Making further progress on international market ramp-up for green hydrogen". Press Release. https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/06/20210614-new-funding-instrument-h2global-launched.html; H2Global (2020) H2Global. https://h2-global.de/

[97] BMWK (previously BMWi) (2021) Minister Altmaier: "Making further progress on international market ramp-up for green hydrogen". Press Release. https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/06/20210614-new-funding-instrument-h2global-launched.html

[98] BMWK (previously BMWi) (2021) €900 million for H2Global hydrogen project Minister Habeck: Launch of hydrogen economy market ramp-up. https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/12/20211223-900-million-euro-for-h2global-hydrogen-project.html

[99] EU Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[100] FCH JU (2019) Hydrogen Roadmap: Europe: A sustainable pathway for the European Energy Transition. https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

[101] EU Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

in Germany, the H2Global mechanism is already at play which aims to scale up the hydrogen market via a Contracts for Difference scheme.[102]

- Germany signed a manifesto with 22 countries to develop a IPCEI in 2021 with a budget of EUR 1.5 billion. This will include R&D for electrolysers (and electrolyser gigafactories), industrialisation of components, fuel cells and other technologies.[103]

Under the 'Fit for 55' package, 13 new legislations and legislative amendments have been proposed at the EU-level. Whilst not yet in place, below are a number of hydrogen-related adjustments that are being considered under the initiative:[104]

- Revision of the Energy Tax Directive (ETD) to disincentivise the use of fossil fuels by lowering rates for hydrogen and renewable products while simultaneously setting higher rates for fossil fuels. Other revisions of the ETD include revising tax reductions and exemptions that lower the taxation of non-renewables.
- The revised Renewable Energy Directive (RED II) may see an increased target from 32% to 40% of final consumption energy coming from renewable energy sources. Sectoral targets for renewable energy sources are also being considered in areas of heating/cooling, transport and industry. Some of these targets may be coupling with binding legislation.
- Implementing the 'ReFuelEU Aviation' Initiative that introduces targets for the use of sustainable aviation fuel and synthetic aviation fuels from 2035-2050. This may potentially be achieved via an EU-established blending mandate with all aircraft leaving EU airports required to refuel using green jet fuels. Sub-mandates for e-fuels, such as electrolysis produced hydrogen, is also under consideration.
- Implementing the 'FuelEU Maritime' Initiative which introduces GHG intensity and reduction requirements to increase demand of renewable and low-carbon fuels in the maritime transport sector.
- The Energy Efficiency Directive (EED) currently sets out that the EU meet 32.5% energy efficiency improvements by 2030. The recast proposes a target of 36-39% by 2030.
- Revising Regulation (EU) 2019/631 (the current CO_2 emission standard for cars and vans). Drafts of the regulation update require a 60-90% cut in emissions from new vehicles by 2030 with penalties for not reaching this target.
- The conversion of the Alternative Fuels Infrastructure Directive into a formal regulation. With reference to hydrogen, this would introduce mandatory deployment targets for electric charging stations and hydrogen refuelling infrastructure for Member States. The revision also seeks to tackle the lack of transparency on pricing and facilitate cross-border payments when recharging e-vehicles.
- Additional regulations on the establishment of a framework to facilitate sustainable investments.

[102] Andreas Franke (2021) Germany launches H2Global system to galvanize green hydrogen imports. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/031721-germany-launches-h2global-system-to-galvanize-green-hydrogen-imports

[103] Christina Dias, Kristina Grigaite and Ines Cunha (2021) Recovery and Resilience Plans – Thematic overview on cross-border projects. Director-General for Internal Policies of the Union, Economic Governance Support Unit.
https://www.europarl.europa.eu/RegData/etudes/IDAN/2021/689472/IPOL_IDA(2021)689472_EN.pdf

[104] European Commission (2021) Proposal for a COUNCIL DIRECTIVE: Restructuring the Union framework for the taxation of energy products and electricity, EUR-Lex Access to European Union Law. < https://eur-lex.europa.eu/legal-content/EN-CS/TXT/?from=pl&uri=CELEX%3A52021PC0563>

1.4 Germany's domestic hydrogen RD&D projects

1.4.1 Major domestic hydrogen RD&D projects

Many RD&D projects are being carried out in Germany, funded by German programs or EU programs. The following resources provide information on specific hydrogen RD&D projects occurring in Germany:

NOW GmbH:

- Project database: https://www.now-gmbh.de/en/projectfinder/?_sfm_projektstatus=active

ERDF (European Regional Development Fund) Cohesion Fund / REACT-EU:

- Project database: https://ec.europa.eu/regional_policy/en/projects

Horizon 2020 / FCH JU (Horizon Europe projects yet to be announced):

- Projects: https://www.fch.europa.eu/fchju-projects/h2020
- Calls for Tenders: https://www.fch.europa.eu/page/procurements

Major RD&D projects of note include:

- **BMBF led projects:** Germany has also launched three hydrogen research projects totalling EUR 700 million, and involving more than 200 companies across Germany:[105]

Table 12: BMBF led projects

Project name	Description	Organisations
H2Giga	Serial production of electrolysers	112 partners including: Thyssenkrupp AG, Siemens Energy AG, SunFire GmbH, Linde PLC ITM Power PLC, MAN Energy Solutions SE, H-Tec Systems GmbH
H2Mare	Researching offshore hydrogen and hydrogen-derivative production	Coordinated by: Siemens Energy, Siemens Gamesa Renewable Energy SA
TransHyDE	Developing, evaluating and demonstrating technologies for hydrogen transport	89 Partners including: RWE Renewables GmbH, GRTgaz SA, Open Grid Europe GmbH, ONTRAS – VNG Gastransport GmbH

- **H2SO Project (2019-2021):** The Fraunhofer ISE (funded by the MoE and State of Baden-Wuerttemberg, and in partnership with 21 private companies, including the DWV) announced a project to investigate the potential of hydrogen production from renewables in Southwest Germany, connecting stakeholders across sectors along the Upper Rhine river with hydrogen and fuel cells.[106]

[105] Franke A (2021) Germany to spend €700M on 3 hydrogen research projects. S&P Global Market Intelligence. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/germany-to-spend-8364-700m-on-3-hydrogen-research-projects-62113936; BMBF (2021) How the hydrogen flagship projects support Germany's entry into the hydrogen economy. Lead Projects. https://www.wasserstoff-leitprojekte.de/leitprojekte

[106] Fraunhofer ISE (2021) H2-SO – Hydrogen Technologies in the Southern Upper Rhine. Research Projects. https://www.ise.fraunhofer.de/de/forschungsprojekte/h2-so.html; DWV (2020) German Hydrogen and Fuel Cell Association: hydrogen Mirror, April 2020. https://www.dwv-info.de/wp-content/uploads/2020/06/ENG_wss2004.pdf

- **H2goesRail (~2024):** Deutsche Bahn (German rail company), in partnership with Siemens launched the H2goesRail project which seeks to develop a hydrogen system for rail transport including hydrogen trains, refuelling and maintenance infrastructure.[107] As part of this project Deutsche Bahn is also collaborating with Wystarch on the development of plug-and-play refuelling station.[108] The first trial operation is due to commence in early 2024.[109]
- **H2Share (2017-2020):** H2Share project (Hydrogen Solutions for Heavy-duty Transport Aimed at the Reduction of Emissions in North-West Europe) aims to provide information and facilitate knowledge in the transport sector. This platform provides a knowledge repertoire of global projects, technical specifications and learnings.[110] The project demonstrated a 27-ton hydrogen truck in April 2020.[111] The project was led by WaterstofNet VZW, along with industry partner organisations and was partly funded by the EU.[112]
- **H2-Kompass (2021-2023):** The H2-Kompass project is co-run and funded by the BMBF and BMWK with aims to map hydrogen innovation across Germany. The project is expected to make an important contribution to future hydrogen roadmaps and policy building by showing areas in which innovation is progressing and areas that may be experiencing barriers to innovation progress.[113]
- **Kopernikus P2X (2019-2022):** The Kopernikus P2X project studies Power-to-X technologies that decouple power from electricity for use in other sectors. The project is currently in its second phase which investigates hydrogen and syngas as two source materials that can be generated via this process. The project is coordinated by DECHEMA, RWTH Aachen and FZJ, and has received EUR 29.7 million in funding from the BMBF.[114]
- **BMUV-led projects:** A number of PtX projects are operated by third parties on behalf of the BMUV. Notably, the PtX Lausitz Lab – a practical laboratory for fuels and raw materials from renewable hydrogen – was established by ZUG gGmbH in March 2021 on behalf of the Federal Ministry.[115] The lab is active in the production and use of PtX products, focusing initially on renewable hydrogen-based synthetic fuels for air and marine vehicles. It also contains a demonstration facility that is utilised by key science and business stakeholders. A second project supported by the BMUV is the PtX Atlas, developed by the Fraunhofer Institute for Energy Economics and Energy System Technology IEE. This Atlas is a world-first interactive map that displays technical and economic assessments of PtX facilities worldwide.[116]

[107] Deutsche Bahn (2021) H2goesRail. https://gruen.deutschebahn.com/en/measures/hydrogen/h2goesrail

[108] Heynes G (2021) Wystrach to provide plug-and-play hydrogen refuelling solutions for the H2goesRail project. H2View. https://www.h2-view.com/story/wystrach-to-provide-plug-and-play-hydrogen-refuelling-solutions-for-the-h2goesrail-project/

[109] FuelCellsWorks (2021) H2goesRail: Hydrogen at Deutschen Bahn. https://fuelcellsworks.com/news/h2goesrail-hydrogen-at-deutschen-bahn/

[110] H2Share (2021) About. https://fuelcelltrucks.eu/about-us/

[111] H2Share (2021) Overview. https://www.nweurope.eu/projects/project-search/h2share-hydrogen-solutions-for-heavy-duty-transport/

[112] H2Share (2021) Overview. https://www.nweurope.eu/projects/project-search/h2share-hydrogen-solutions-for-heavy-duty-transport/

[113] BMBF & BMWK (previously BMWi) Federal government launches hydrogen compass: The H2 compass project is intended to show progress in hydrogen innovations [Joint Press Release]. https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/06/20210602-Bundesregierung-startet-Wasserstoff-Kompass.html

[114] BMBF (n.d.) Power-to-X in Germany: These projects are already existing. https://www.kopernikus-projekte.de/en/projects/p2x/ptx_projects

[115] PtX Lab Lausitz (n.d.) About Us. https://ptxlablausitz.de/ueber-uns/

[116] Fraunhofer IEE (n.d.) Global PtX Atlas. https://maps.iee.fraunhofer.de/ptx-atlas/

1.4.2 Major domestic commercial hydrogen projects

IPCEI Projects in Germany: Major commercial projects of note in Germany include 62 large-scale hydrogen projects selected in May 2021 as part of the joint European hydrogen project (IPCEI) by the BMVI and BMWK. These projects are jointly funded by IPCEI Hydrogen, including the German government and private investors together with up to 22 European partner countries, totalling EUR 33 billion. This is made up of EUR 4.4 billion from the BMWK, EUR 1.4 billion from the BMVI, EUR 20 billion from private investors, and the remainder from state funding.[117] A project pipeline of 62 projects are in Germany covering the entire value chain of the hydrogen market.[118]

German involvement in IPCEI Projects across Europe: Germany is also involved in a pipeline of hydrogen projects in other European countries, many of which cut across borders into Germany. Examples include 'Green Hydrogen @ Blue Danube', 'Green Flamingo', 'Green Spider', 'Silver Frog', 'White Dragon', 'H2Go', 'Zero-emission Urban Delivery @ Rainbow UnHycorn' and 'Blue Dolphin'.[119]

1.4.3 Germany's hydrogen RD&D clusters

In December 2019 the German government selected 13 "HyExpert" and 3 "HyPerformer" regions. EUR 300,000 was awarded to each HyExpert winner, for the development of hydrogen project concepts and ideas. EUR 20 million was awarded for the HyPerformer regions in the form of grants for implementation of existing concepts in hydrogen and fuel cell technologies. The total funding for the HyPerformer projects (including the government grants) amount to EUR 195 million. The second round of the HyLand competition was launched from April to June 2021, and the 30 winners were announced in September 2021. Each HyStarter winner (an initiative of the HyLand competition) will receive one year of expert and organisational help to establish a regionally tailored hydrogen concept and network of local hydrogen stakeholders. Each HyExpert winner (another initiative of the HyLand competition) each receive EUR 400,000[120] to plan and calculate specific hydrogen project proposals.

Hydrogen clusters are geographical locations where the hydrogen value chain is integrated thus improving project costs. Germany has five major regions that are particularly suitable for power-to-gas clusters (also known as valleys, hubs, or ecosystems),[121] and already have several integrated cluster projects that are under development or in operation. [122] The H2Rivers, HyBayern and Hyways4Future clusters were winners of the HyPerformer grants in 2019. Germany's hydrogen clusters are shown in Figure 8 below.

[117] BMWi (2021) "We want to become number 1 in the world in hydrogen technologies": BMWi and BMVI are launching 62 large-scale hydrogen projects. Joint Press Release. https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210528-bmwi-und-bmvi-bringen-wasserstoff-grossprojekte-auf-den-weg.html

[118] BMWK (previously BMWi) IPCEI Locations https://www.bmwi.de/Redaktion/DE/Downloads/I/ipcei-standorte.pdf?__blob=publicationFile&v=6

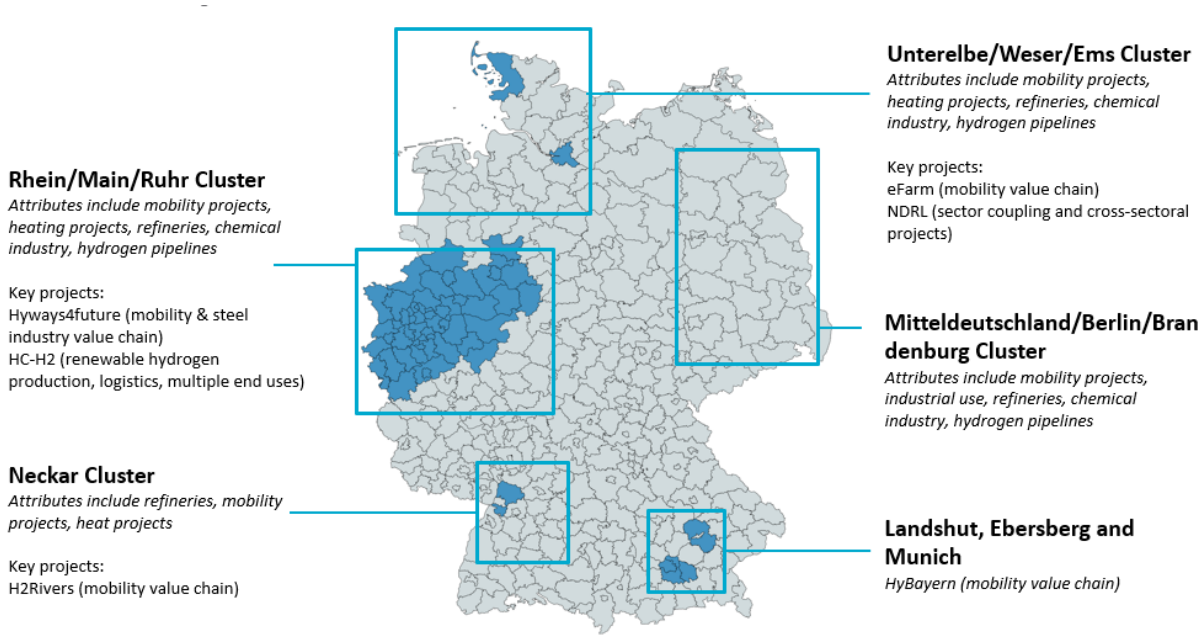
[119] Trinomics and Ludwig böklow systemtechnik (2020) Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans. Prepared for the FCH JU, EU.

[120] Biogradlija A (2021) Hyland launches second round with 30 new regions. Energy News. https://energynews.biz/hyland-launches-second-round-with-30-new-regions/

[121] DENA (2016) Power to Gas Potentiality Atlas [In German] https://www.dena.de/fileadmin/dena/Dokumente/Presse___Medien/9144_Studie_Potenzialatlas_Power_to_Gas.pdf

[122] Mission Innovation (2021) Hydrogen Valleys. https://www.h2v.eu/hydrogen-valleys?populate=&field_ch_1_q_10_value=DE; FCH JU (2019) Hydrogen Regions get Further Support in Germany https://www.fch.europa.eu/news/hydrogen-regions-get-further-support-germany; Forschungszentrum Jülich (2021) € 860 Million in Funding: Rhineland to Become a Model Region for Hydrogen Tech [Press Release]. https://www.fz-juelich.de/SharedDocs/Pressemitteilungen/UK/EN/2021/2021-09-03-hc-h2.html

Figure 8: Germany's hydrogen clusters[123]



Rhein/Main/Ruhr Cluster

- **Hyways4future (2020-2024):** The objective of the project is to demonstrate the hydrogen value chain in industry and mobility applications. The project sources energy from the grid, and produces hydrogen using PEM electrolysis, which is then compressed, stored and transported for use in a range of mobility applications and the steel industry. The project lead is EWE AG, the project has over 90 partners, and is sponsored by the BMVI and the NIP2 program. Main locations are Bremen, Bremerhaven, Cuxhaven, Oldenburg, Wilhelmshaven.[124]
- **Helmholtz Cluster for the Hydrogen Economy (HC-H2):**[125] Forschungszentrum Jülich is set to establish a 'Helmholtz Cluster for a Sustainable and Infrastructure-Compatible Hydrogen Economy' in the North Rhine-Westphalia region, which will receive EUR 860 million in funding from the BMBF over a 17-year period. The cluster will focus its RD&D efforts across areas of renewable hydrogen production, usage, and logistics, and the integration of these technologies into existing infrastructure. Features of the cluster include a hydrogen demonstration region and an innovation centre operated by Forschungszentrum Jülich.

Neckar Cluster

- **H2Rivers (2019-2023):** H2Rivers is the establishment of hydrogen generation and distribution with a focus on mobility applications, and covers several areas of the value chain including hydrogen production (PEM electrolysis and steam-methane reforming), storage and transportation of compressed hydrogen, and utilisation in fuel cell cars, buses and forklifts. It is led by EWE AG and

[123] Mission Innovation (2021) Hydrogen Valleys. https://www.h2v.eu/hydrogen-valleys?populate=&field_ch_1_q_10_value=DE; FCH JU (2019) Hydrogen Regions get Further Support in Germany https://www.fch.europa.eu/news/hydrogen-regions-get-further-support-germany; Forschungszentrum Jülich (2021) € 860 Million in Funding: Rhineland to Become a Model Region for Hydrogen Tech [Press Release]. https://www.fz-juelich.de/SharedDocs/Pressemitteilungen/UK/EN/2021/2021-09-03-hc-h2.html

[124] FCH JU and Mission Innovation (2021) Hyways for Future https://www.h2v.eu/hydrogen-valleys/hyways-future

[125] Forschungszentrum Jülich (2021) € 860 Million in Funding: Rhineland to Become a Model Region for Hydrogen Tech [Press Release]. https://www.fz-juelich.de/SharedDocs/Pressemitteilungen/UK/EN/2021/2021-09-03-hc-h2.html

sponsored by the BMVI and the NIP2. Primary locations include Bremen, Bremerhaven, Cuxhaven, Oldenburg and Wilhelmshaven.

Unterelbe/Weser/Ems Cluster

- **NDRL (Norddeutsches REallabor Living Lab) (2018-2026):** The North German Real Laboratory is focused on testing the transformation of the energy system, sector coupling and cross-sectoral projects.[126] This cluster involves 50 partners across industry, research and government, and is sponsored by the BMWK, BMVI and BMUV.[127] The main location of this cluster is Hamburg.
- **eFarm (2020):** Addresses the complete value chain in the mobility sector, including hydrogen production from renewables, refuelling stations, and a fleet of hydrogen buses and fuel cell cars. [128] This cluster is led by GP JOULE Think GmbH & Co. KG, and has 20 regional shareholders and 13 additional partners, and is sponsored by the BMVI and the district of Nordfriesland.[129] The main location for the project is Reuβenköge.

Landshut, Ebersberg and Munich

- **HyBayern (2019-2025):** The objective of the project is to establish a closed cycle of hydrogen production from renewables, distribution and use. Hydrogen is to be produced via PEM electrolysis and is transported via trucking of compressed hydrogen, and utilisation in cars and buses. This project is led by the District Office of Landshut, and sponsored by three administrative districts (Landshut, Ebersberg and Munich), and is also sponsored by multiple other partners. The main location of the project is in Landshut.[130]

1.5 International collaboration and joint RD&D projects

1.5.1 Overview of Germany's approach to international collaboration

There are several references to international collaboration in Germany's *National Hydrogen Strategy*. These relate to international trade relations for Germany, technological collaboration, and collaboration for demonstrations. Germany identifies international collaboration as a way to open opportunities in the fields of climate change mitigation and foreign, economic and development policy.

- **International trade:** Germany has identified that hydrogen has the potential to open up many international trade opportunities. It is expected that this will become a significant industrial and geopolitical factor and will offer fresh opportunities for collaboration. Specifically, Germany discusses the integration of hydrogen into existing energy partnerships and the establishment of new energy partnerships with countries that open up new opportunities for trade and growth.
- **Technological collaboration:** The strategy outlines how global cooperation is an opportunity for technological advancement for hydrogen and can provide mutual sustainable growth and development for collaborating countries. In particular, the Strategy outlines existing international

[126] BMWK (previously BMWi) (2021) Launch of the Northern Germany Regulatory Sandbox: Economic Affairs Ministry provides more than €52 million in funding [Press Release], German Bundestag. Viewed at https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/04/20210414-norddeutsches-reallabor-gestartet.html

[127] FCH JU and Mission Innovation (2021) NDRL (Norddeutches Reallabor – Living Lab Northern Germany. https://www.h2v.eu/hydrogen-valleys/ndrl-norddeutsches-reallabor-living-lab-northern-germany

[128] GP Joule (2021) E-Farm https://www.gp-joule.eu/references/cross-sector-linkage/efarm-1

[129] FCH JU and Mission Innovation (2021) EFarm https://www.h2v.eu/hydrogen-valleys/efarm

[130] FCH JU and Mission Innovation (2021) HyBayern. https://www.h2v.eu/hydrogen-valleys/hybayern

activities such as the International Partnership for Hydrogen and Fuel Cells in the Economy, the International Renewable Energy Agency and the International Energy Agency.

- **Demonstrations:** Germany states that international collaboration will come in the form of pilot projects in partner countries. These pilot projects are intended to be across the entire supply chain. Germany aims to ensure that these projects are additional to domestic energy production in the partner country and do not impede the supply of renewable energy.

1.5.2 Germany's bilateral hydrogen relationships

Germany is engaging the international community in several bilateral and multilateral forums in the area of hydrogen. Examples include:

- Co-leading the 'IC8: Renewable and Clean Hydrogen' challenge as part of Mission Innovation, an international platform for catalysing action and investment in RD&D for clean energy.[131]
- Participating in the HyLaw project includes 23 partners from 16 EU countries, the UK and Norway to develop benchmarks for the removal of legal barriers to the deployment of fuel cells and hydrogen applications in each country.[132]
- In 2021 Germany and the United Arab Emirates (UAE) published a study on *The Role of Hydrogen for the Energy Transition in the UAE and Germany*[133] summarising joint activities in hydrogen and potential future cooperation. This study was commissioned as part of the Emirati-German Energy Partnership initiated in January 2017. The partnership assesses the role for hydrogen, namely the potential for export from the UAE to Germany.

In addition to this, Germany has engaged in a number of formal relationships with other countries. These are detailed in Table 13 below.

Table 13: Bilateral relationships with other countries

Country	Relationship	Description
International	Partnerships	Separate to the agreements above, Germany's BMWK holds formal energy partnerships with over 20 countries. Countries include Algeria, Australia, Belarus, Brazil, Canada, Chile, China, Ethiopia, India, Iran, Japan, Jordan, Kazakhstan, Morocco, Mexico, Republic of Korea, Russia, South African, Tunisia, Turkey, Ukraine, UAE, USA and Uzbekistan.[134]
Australia	Declaration of Intent	Due to limited renewable resources, Germany is engaging Australia in their development of a hydrogen economy.[135] With significant renewable potential across Australia, Germany has engaged in a number of initiatives:

[131] Mission Innovation (2021) IC8: Renewable and Clean Hydrogen. http://mission-innovation.net/our-work/innovation-challenges/renewable-and-clean-hydrogen/

[132] Harms G et al. (2018) HyLAW National Policy Paper – Germany. https://www.hylaw.eu/sites/default/files/2018-12/20181217_National%20Policy%20Paper%20DE%20en%20Final_0.pdf

[133] Schröder J et al. (2021) The Role of Hydrogen for the Energy Transition in the UAE and Germany. UAE Ministry of Energy & Infrastructure and BMWi

[134] BMWK (previously BMWi) (2020) Energiepartnerschaften und Energiedialoge: Annual Report 2020. https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/jahresbericht-energiepartnerschaften-2020.pdf?__blob=publicationFile&v=4

[135] Finkel A (2021) Getting to Zero: Australia's Energy Transition. Quarterly Essay, Issue 1, 2021.

Country	Relationship	Description
		Australia and Germany in September 2020 signed an Joint Declaration of Intent to deliver the 'HySupply German-Australian Supply Chain Feasibility Study of Hydrogen produced from Renewables'. The study will analyse the entire hydrogen supply chain to establish how Australia can best deliver renewable hydrogen to Germany and will consider the trade of technological innovations between the countries.[136] German 'International Future Labs' is a collaborative initiative announced in February 2021 to bring international researchers together to advance research on using renewable energy to produce hydrogen from renewables. The ministry (Bundesministerium für Bildung und Forschung) says the focus is on collaboration with the EU, North America, Africa, Israel, Russia and Australia.[137] In June 2021 the Australian and German governments announced the 'Declaration of Intent between the Government of Australia and the Government of Germany on the Australia-Germany Hydrogen Accord'. This Accord seeks to build on each country's strengths, with Germany being a world leader in hydrogen technology and planning to import significant quantities of hydrogen, and Australia looking to be a major hydrogen exporter, to facilitate greater collaboration on technological innovation.[138] The German-Australian Hydrogen Innovation and Technology Incubator (HyGATE) falls under this accord.
UAE	Declaration of Intent	In November 2021, the Ministry of Energy and Infrastructure of the United Arab Emirates and the Federal Ministry for Economic Affairs and Energy of Germany signed a joint declaration on 'The Establishment of a Bilateral Task Force on Hydrogen and Synthetic Fuels (Emirati-German Hydrogen Task Force)'.[139]
USA	Partnership	In July 2021, President Biden and Chancellor Merkel launched the US-Germany Climate and Energy Partnership. The Partnership seeks to strengthen high-level collaboration on clean energy technologies and the policy necessary to achieve net-zero emissions. The Partnership includes three key areas of cooperation: 'Climate Action'; 'Transformational Energy Technologies'; and 'Energy Transitions in Emerging Economies'. With respect of the 'Transformation Energy Technologies pillar, key areas of focus include joint collaboration on RD&D on

[136] Minister for Industry, Energy and Emissions Reduction (2020) Media Release: Positioning Australia as a future hydrogen export powerhouse , https://www.minister.industry.gov.au/ministers/taylor/media-releases/positioning-australia-future-hydrogen-export-powerhouse>

[137] Burke F (2021) Germany launches future labs for green hydrogen. Science Business. https://sciencebusiness.net/news/germany-launches-future-labs-green-hydrogen

[138] Prime Minister of Australia (2021) Australia and Germany Partner on Hydrogen Initiatives. https://www.pm.gov.au/media/australia-and-germany-partner-hydrogen-initiatives.

[139] MOEI (United Arab Emirates) and BMWK (previously BMWi) (2021) Joint Declaration of Intent on the Establishment of a Bilateral Task Force on Hydrogen and Synthetic Fuels (Emirati-Hydrogen Task Force). https://www.bmwi.de/Redaktion/EN/Publikationen/Aussenwirtschaft/joint-declaration-of-intent-between-the-ministry-of-energy-and-infrastructure-of-the-united-arab-emirates.pdf?__blob=publicationFile&v=3

Country	Relationship	Description
		sustainable hydrogen and energy technologies RD&D, the acceleration of renewable energy technologies and grid integration of variable renewable energy, the development of resilient energy systems and facilitation of technology commercialisation from research institutions.[140] In 2017, the DOE's Fuel Cell Technologies and Germany's NOW GmbH announced a collaboration on hydrogen safety R&D. Key areas of focus include refuelling station equipment, liquid hydrogen, tunnel safety among other areas.[141]
Chile	Letter of intent/ Declaration	Germany and Chile in July 2021 signed a declaration to strengthen cooperation on the production of hydrogen from renewables by establishing a working group within the Chilean-German Energy Association to identify viable projects, develop international supply chains, and share knowledge.[142] Germany and Chile in June 2020 signed a Letter of Intent to collaborate on hydrogen production and to create a renewable hydrogen supply chain between the two countries.[143]
The Republic of Korea	MoU	In April 2021, the German Hydrogen and Fuel Cell Association (DWV) signed an MoU with K2Korea to promote international cooperation in hydrogen industry development and accelerate technical development.[144]
Russia	MoU	Germany and Hydrogen signed an MoU in April 2021 to distribute hydrogen via the gas pipeline Nord Stream 2. The MoU totalled EUR 2 billion.[145]
Canada	MoU	In March 2021 Canada and Germany signed an MoU to collaborate on their clean-energy transitions. With respect to hydrogen, the focus was on fostering the transition toward low-carbon fuels and increasing usage of renewable energy in the transport, heating and industrial sectors through collaboration on production, usage and trade of clean hydrogen.[146]

[140] The White House (2021) Fact Sheet: US-Germany Climate and Energy Partnership https://www.whitehouse.gov/briefing-room/statements-releases/2021/07/15/fact-sheet-u-s-germany-climate-and-energy-partnership/

[141] DOE (2017) DOE and Germany's NOW Collaborate on Hydrogen Safety R&D. https://www.energy.gov/eere/fuelcells/articles/doe-and-germany-s-now-collaborate-hydrogen-safety-rd

[142] Sergio Matalucci (2021) The Hydrogen Stream: Chile and Germany join forces to develop viable green hydrogen projects. https://www.pv-magazine.com/2021/07/02/the-hydrogen-stream-chile-and-germany-join-forces-to-develop-viable-green-hydrogen-projects/

[143] Reuters (2021) Germany and Chile sign accord to boost hydrogen cooperation. https://www.reuters.com/business/energy/germany-chile-sign-accord-boost-hydrogen-cooperation-2021-06-29/

[144] H2Korea and DWV (2021) H2Korea and DWV signed a Memorandum of Understanding to realize the Hydrogen Economy of both countries and foster related industries. Press Release. https://www.dwv-info.de/wp-content/uploads/2021/05/20210531-PM-H2Korea-DWV-EN-DW-final.pdf

[145] Reuters (2021) UPDATE-2Germany, Russia flag hydrogen cooperation. https://www.reuters.com/article/russia-germany-gas-idUSL8N2MM4CX

[146] Dentons (2021) Canada and Germany sign MOU in Clean Energy. Insights. https://www.dentons.com/en/insights/alerts/2021/march/18/canada-and-germany-sign-mou-on-clean-energy

Country	Relationship	Description
Saudi Arabia	MoU	Germany and Saudi Arabia signed an MoU in March 2021 to collaborate in the field of hydrogen production from renewables.[147]
Morocco	Cooperation Agreement	Morocco and Germany signed an agreement in June 2020 to collaborate on technology development in the production of hydrogen from renewables. The agreement aims to establish joint projects for research, development and investment for renewable hydrogen.[148]
Japan	Partnership	The Japanese-German Energy Partnership, signed June 2019, is structured into two working groups. The first focuses primarily on a broader energy transition, with the second focusing on hydrogen – specifically on market ramp-up of renewable hydrogen production, expansion of supply chains, joint international certification standards, and the use of hydrogen to decarbonise industry sectors.[149]
China	Partnership	In 2020 a series of workshops was held with respect to the prospects of cooperation in the field of renewable hydrogen. China and Germany have leveraged the Sino-Germany Energy Partnership (originally signed in January 2006), to facilitate information sharing for the production and utilisation of hydrogen produced from renewable sources.[150]
India	Partnership	India and Germany have longstanding renewable energy collaborations including through the Indo-Germany Solar Energy Partnership (October 2015), Indo-German Energy Programme (2015), and the Indo-German Energy Forum (2006).[151] While these agreements largely concern solar power, there is potential for expansion into other renewable sectors, with India and Germany announcing in September 2021 that they will make a concerted effort to build stronger and more impactful energy partnerships.[152]

[147] Informa (2021) Germany and Saudi Arabia sign green hydrogen agreement. Energy & Utilities. https://energy-utilities.com/germany-and-saudi-arabia-sign-green-hydrogen-news111261.html

[148] FuelCellsWorks (2020) Morocco, Germany Sign Green Hydrogen Cooperation Agreement. https://fuelcellsworks.com/news/morocco-germany-sign-green-hydrogen-cooperation-agreement/

[149] FuelCellsWorks (2019) German-Japanese Energy Partnership Creates Momentum for Energy Transition. https://fuelcellsworks.com/news/german-japanese-energy-partnership-creates-momentum-for-energy-transition/; Adelphi (n.d.) Energy Partnership with Japan and Korea. https://www.adelphi.de/en/project/energy-partnership-japan-and-korea#:~:text=The%20Japanese%2DGerman%20Energy%20Partnership,renewable%20energies%2C%20especially%20offshore%20wind.

[150] Tim Nees (n.d.) China and Germany – Exchanging on Green Hydrogen Strategies, Energiepartnerschaft. https://www.energypartnership.cn/newsroom/hydrogen/#:~:text=China%20too%20has%20formulated%20ambitious,such%20as%20fuel%20cell%20vehicles.&text=Hence%2C%20within%20the%20Sino%2DGerman,produced%20from%20renewable%20energy%20sources.

[151] BMZ and MNRE (2015) Memorandum of Understanding on Indo-German Development Cooperation regarding the Indo-German Solar Energy Partnership. https://mnre.gov.in/img/documents/uploads/b5328848e5dd4a6e9b7d6b09446ee077.pdf; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (n.d.) Indo-German Energy Programme (IGEN). https://www.giz.de/en/worldwide/15767.html; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (n.d.) Indo-German Energy Forum. https://www.giz.de/en/worldwide/15850.html

[152] Press Trust of India (2021) India, Germany will work to build stronger energy, climate partnerships. https://www.business-standard.com/article/economy-policy/india-germany-will-work-to-build-stronger-energy-climate-partnerships-121090901376_1.html

1.5.3 Germany's joint international RD&D projects

Other Countries

Germany engages in several hydrogen RD&D projects multilaterally and bilaterally. Recent projects are shown in Table 14.

Table 14: Germany's joint international RD&D projects

Country	Projects
International	Germany has established 'International Future Laboratories' that aims to foster international collaboration for hydrogen production from renewables. The BMBF states that the focus will be on the EU, North America, Africa, Israel, Russia and Australia. The first research projects are due to begin December 2021.[153] Furthermore, the International Power-to-X Hub Berlin has been established as part of the International Climate Initiative. The Hub, which supports sustainable businesses and projects by providing networks and fostering market development, is led by the GIZ GmbH on behalf of the BMUV. Projects are conducted bilaterally, between the Berlin hub and a local partner in the participating country. Current projects are in Morocco, Argentina, Chile and Brazil.[154]
Australia	**HyGATE:** Germany and Australia in November 2021 announced the proposed German-Australian Hydrogen Innovation and Technology Incubator to support R&D projects across the hydrogen supply-chain. Australia has committed AUD 50 million and Germany has committed EUR 50 million to the initiative.[155] HyGATE follows the signing of the Australia-Germany Hydrogen Accord in June 2021. **HySupply:** Australia and Germany in September 2020 signed a Joint Declaration of Intent to deliver the 'HySupply German-Australian Supply Chain Feasibility Study of Hydrogen produced from Renewables'. This study is to investigate a supply chain involving all areas of the chain. Its primary aim is to investigate the feasibility of the entire value chain for green hydrogen between Germany and Australia and also to develop business-models for a long-term partnership between the two countries.[156]
Korea	The Korea Institute of Energy Technology and Fraunhofer of Germany established the Green Hydrogen Joint Research Centre in July 2021.[157]
Russia	In July 2021, the Russian government established a working group on hydrogen production with Germany, France and Australia. Through the working group, Russia has flagged that there is scope for joint hydrogen projects between member countries and their industry leaders.[158]

[153] Burke F (2021) Germany launches future labs for green hydrogen. Science Business. https://sciencebusiness.net/news/germany-launches-future-labs-green-hydrogen

[154] International PtX Hub Berlin (2022) Partner Projects. https://ptx-hub.org/projects/

[155] Prime Minister of Australia (2021) Australia and Germany Partner on Hydrogen Initiatives. Media Release. https://www.pm.gov.au/media/australia-and-germany-partner-hydrogen-initiatives

[156] Acatech (2020) HySupply – German-Australian Feasibility Study of Hydrogen produced from Renewables. https://en.acatech.de/project/hysupply-german-australian-feasibility-study-of-hydrogen-produced-from-renewables/

[157] FuelCellsWorks (2021) Korea Institute of Energy Technology and Fraunhofer of Germany Establish the Green Hydrogen Joint Research Center. https://fuelcellsworks.com/subscribers/korea-institute-of-energy-technology-and-fraunhofer-of-germany-establish-the-green-hydrogen-joint-research-center/

[158] Argus Media (2021) Russia gathers firms to develop hydrogen industry. https://www.argusmedia.com/en/news/2236671-russia-gathers-firms-to-develop-hydrogen-industry

Country	Projects
Morocco	In June 2020, Morocco and Germany announced two joint projects through a Cooperation Agreement. These are the PtX project for hydrogen production from renewables by the Moroccan Solar Energy Agency (MASEN), and a PtX research platform to facilitate transfer of knowledge and skills development in partnership with the Institute for Research in Solar Energy and New Energy (IRESEN).[159]

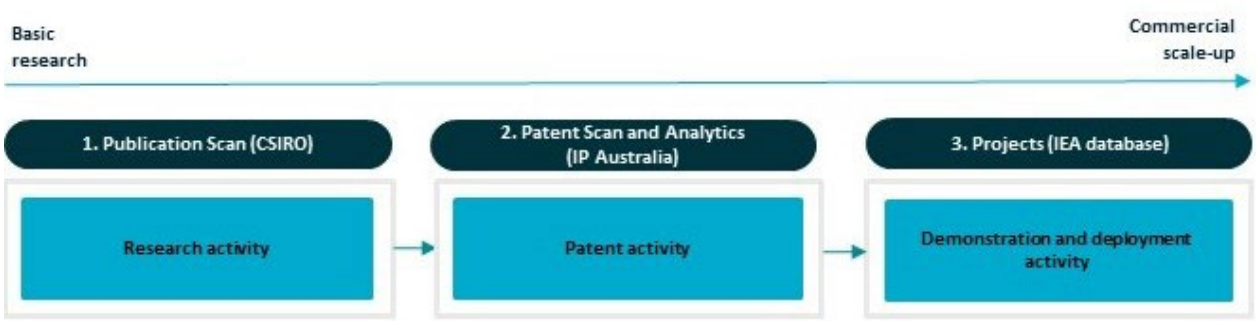
1.5.4 Germany's joint international commercial projects

1.6 Data insights: Germany's hydrogen RD&D activity

The following section provides data-driven insights on Germany's RD&D activity in hydrogen technologies. Research publication data, patent data, and commercial project data has been used to understand hydrogen related activity. While limitations exist with such an approach, these data sources do provide an opportunity to consider activity across the innovation spectrum from basic research to demonstration. It also aims to help identify technology areas that have received significant focus in each country and key organisations to support international collaboration efforts.

The data for this section was sourced from CSIRO's publications team, CSIRO's IP team, IP Australia, and the IEA's hydrogen projects database.

Figure 9: Hydrogen innovation activity data



1.6.1 Research publication data

Research publications in hydrogen are an indicator of basic and applied research activity. CSIRO's publications team has conducted a research publication scan to identify German organisations conducting research across the hydrogen value chain. The publications search approach was developed in 2019 to support the report *Hydrogen Research, Development and Demonstration: Priorities and opportunities for Australia*. This search approach was applied in 2021 to provide an updated dataset for this report. The details of the search approach can be found in the *National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository*.[160]

[159] FuelCellsWorks (2020) Morocco, Germany Sign Green Hydrogen Cooperation Agreement. https://fuelcellsworks.com/news/morocco-germany-sign-green-hydrogen-cooperation-agreement/

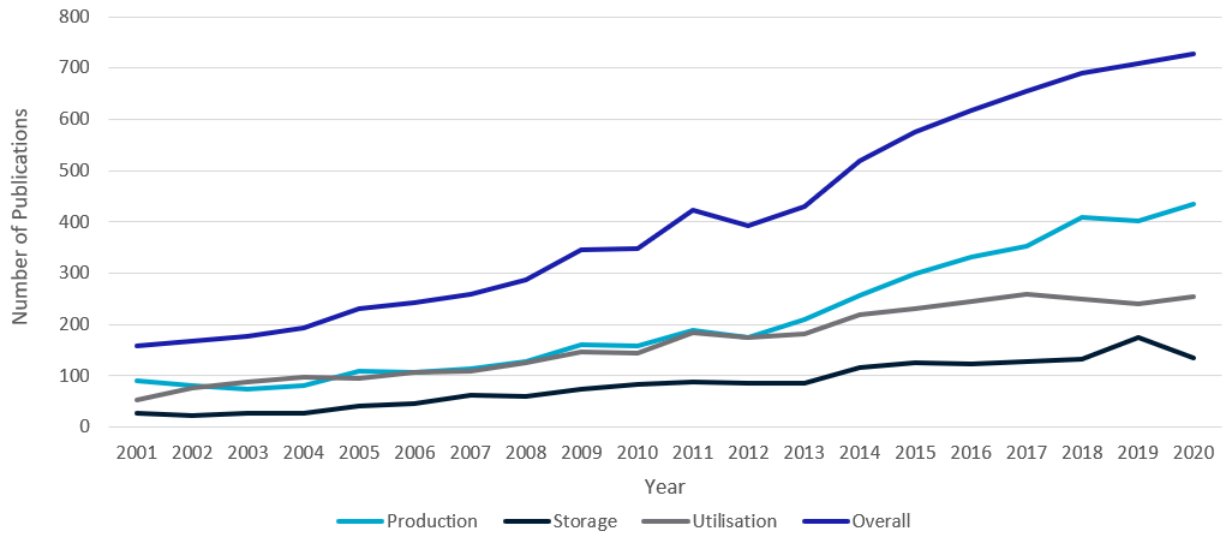
[160] CSIRO (2019) National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository. Available at https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/futures-reports/hydrogen-research

Figure 10 shows German institutions ranked in terms of publication output across hydrogen production, storage and distribution, and utilisation from 2016-2020. Figure 11 shows Germany's country-wide research publication output trends across the hydrogen value chain.

Figure 10: Top institutions by publication output (2016-2020)

Rank	Production	Storage and Distribution	Utilisation	Overall
	4th Global Rank	*3rd Global Rank*	*4th Global Rank*	*4th Global Rank*
1st	Helmholtz Association	Helmholtz Association	Helmholtz Association	Helmholtz Association
2nd	Max Planck Society	Max Planck Society	Max Planck Society	Max Planck Society
3rd	Karlsruhe Institute of Technology	University of Erlangen Nuremberg	RWTH Aachen University	Karlsruhe Institute of Technology
4th	University of Erlangen Nuremberg	Karlsruhe Institute of Technology	Technical University of Munich	RWTH Aachen University
5th	RWTH Aachen University	RWTH Aachen University	Karlsruhe Institute of Technology	University of Erlangen Nuremberg

Figure 11: Germany's hydrogen-related research publication output (2001-2020)



1.6.2 Patent data

Patent activity in hydrogen is an indicator of applied R&D and innovation occurring across the value chain. This section draws on two different patent analytics approaches. CSIRO developed a search approach in 2019 to support the *Hydrogen Research, Development and Demonstration: Priorities and opportunities for Australia* report. CSIRO applied this approach to provide a patent landscape across the hydrogen value chain for each country. The details of the search approach and any limitations can be found in the *National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository*.[161] The second approach, performed by IP Australia, builds on the hydrogen technology taxonomy developed in CSIRO's 2019 report to provide information on specific hydrogen technologies that sit within production, storage

[161] CSIRO (2019) National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository. Available at https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/futures-reports/hydrogen-research

and utilisation. The full data visualisations, details of the search approach and any limitations can be found at *Patent analytics of hydrogen technologies: an interactive visualisation.*[162]

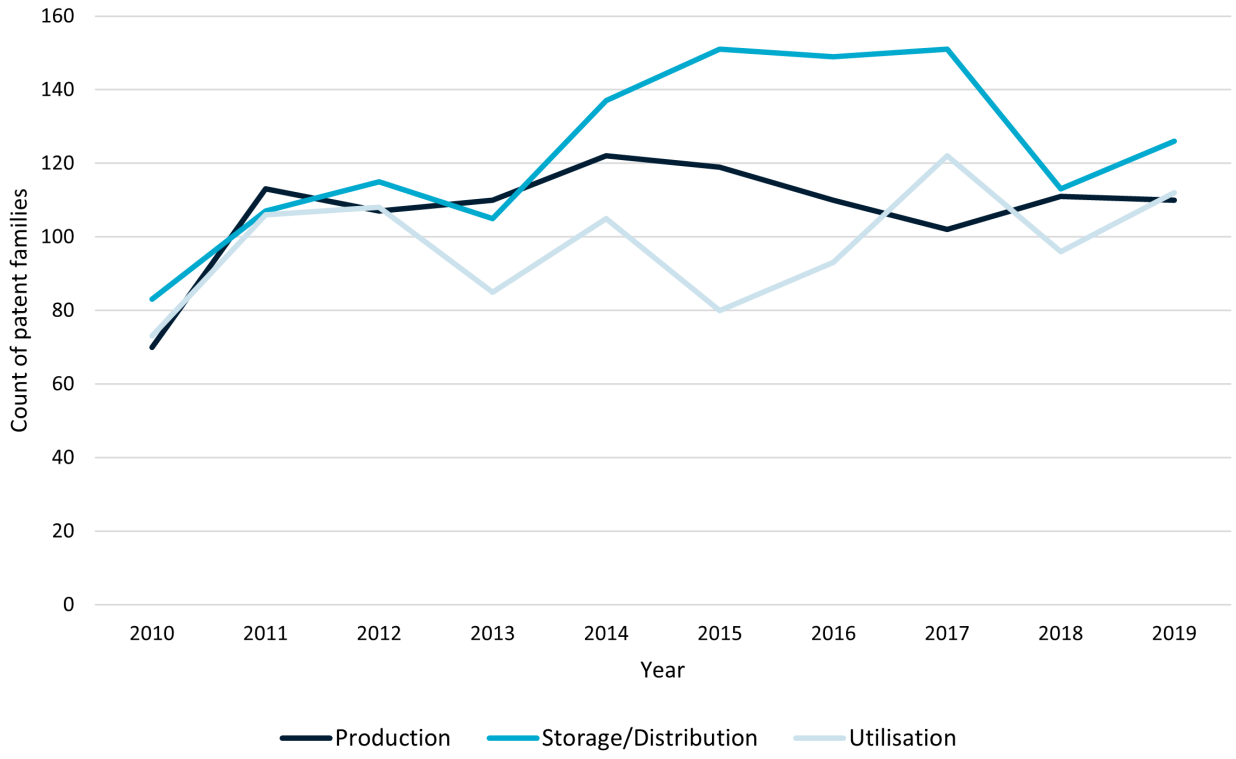
It should be noted that analysis of patent data is not necessarily representative of patent impact. As such, this data should be viewed holistically with the other data presented in this section, particularly project deployment.

Patent landscape of hydrogen value chain

Performed by the CSIRO, this patent landscape analyses patent family[163] filings across the hydrogen value chain. Figure 12 outlines patent filings over time across the areas of hydrogen production, storage/distribution and utilisation. Figure 13 shows the jurisdictions in which German patent applicants are filing patents, outside of Germany. This provides an indication of which global markets, or manufacturing/commercialisation destinations are of interest to German patent applicants or inventors.

Note that patent databases have a delay of roughly 18 months, therefore 2020 and 2021 have been omitted from the graphs below. Some patent filings may also be counted twice as the categories of production, storage and utilisation may not be mutually exclusive in all instances and some could relate to multiple areas of the hydrogen value chain.

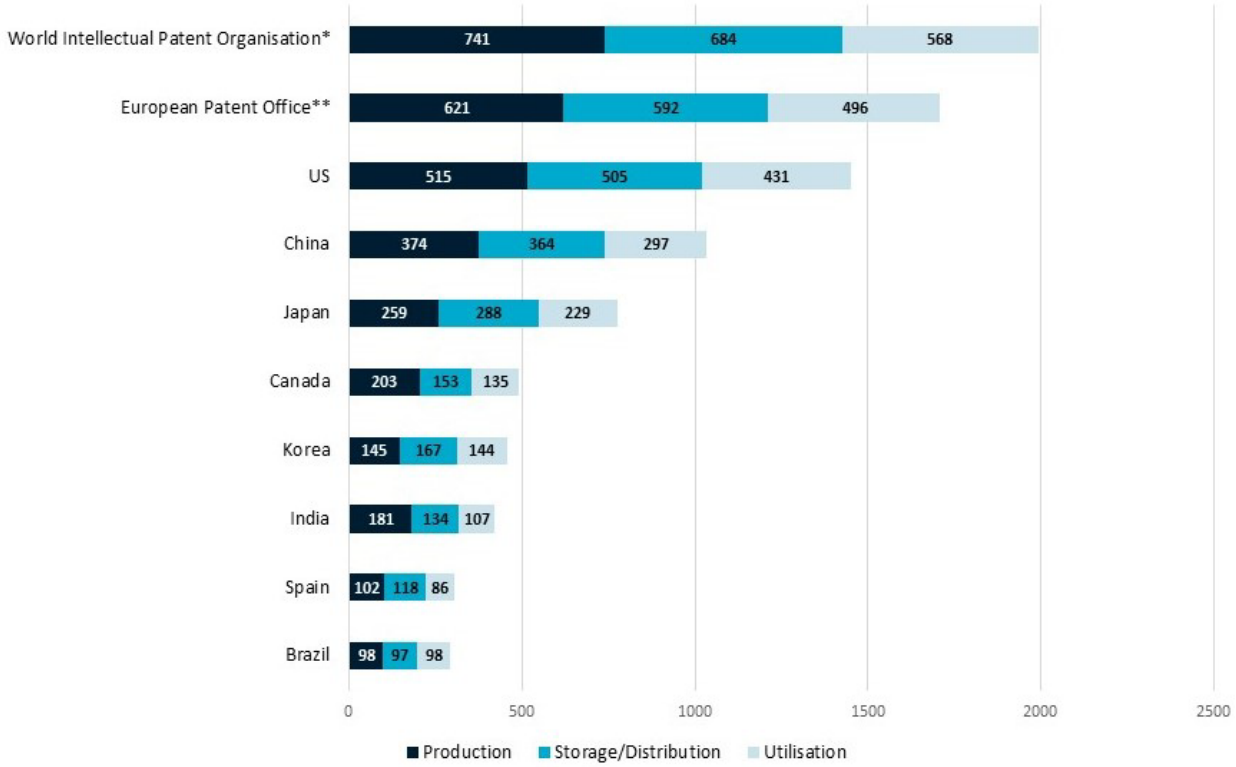
Figure 12: Patent filings over time across production, storage/distribution and utilisation



[162] IP Australia (2021) Patent Analytics on Hydrogen Technology, Australian Government. Available at https://www.ipaustralia.gov.au/tools-resources/publications-reports/patent-analytics-hydrogen-technology

[163] Applications with the same priority, but filed in different jurisdictions, are known as patent families. Patent families enable us to analyse inventive activity regardless of the number of countries in which protection is sought. Patent families are used in analytics to represent a single invention.

Figure 13: Location of patents filings by German patent applicants



*** The World Intellectual Property Organisation (WIPO) is an international organisation that promotes the protection of intellectual property and supervises administrative cooperation amongst the intellectual unions regarding protection of intellectual property. Patents filed in the WIPO enable applicants to obtain protection for their inventions in up to 153 of the parties to the Patent Cooperation Treaty.**

**** The European Patent Office enables investors, researchers and companies to obtain protection for their inventions in up to 44 countries, including all 27 EU member states.**

Patent analytics of specific hydrogen technologies

Data extracted from IP Australia's interactive visualisation provides an in-depth analysis of specific hydrogen technology developments. Figure 14 shows the number of patent families filed since 2010 for specific technology areas by German applicants.

Table 15 shows the number of patent families filed by German applicants since 2010 by sub-technology area, expressed as a percentage of total global patent family filings. Table 15 also shows the top organisations in German filing patents in each technology area. It should be noted that the majority of fuel cell technologies are categorised under the 'electricity generation' category.

Figure 14: Germany's patent family output by sub-technology area (2010-2020)

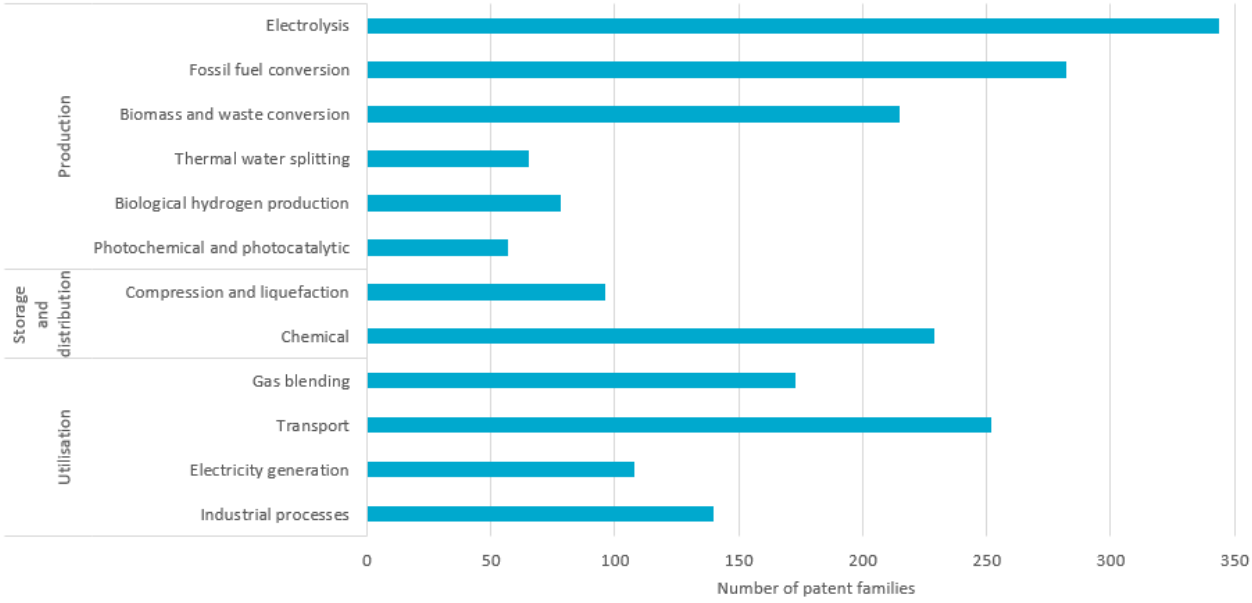


Table 15: Germany's IP output (number of patent families filed by German applicants) by sub-technology area from 2010-2020

Technology area		IP output (% of global)	Leading companies	Leading non-profits and universities
Production	Electrolysis	4.3%	Siemens, Robert Bosch, Thyssen Krupp, Etogas, Linde	Helmholtz-Zentrum Berlin Fuer Materialien Und Energie, Fraunhofer, Forschungszentrum Jülich, Deutsches Zentrum Fuer Luft- und Raumfahrt
	Fossil fuel conversion	4.6%	Linde, BASF, Thyssen Krupp, Siemens	Fraunhofer, Technische Universitaet Muenchen, Technische Universitaet Bergakademie Freiberg
	Biomass and waste conversion	7.2%	Linde, BASF, Thyssenkrupp Industrial Solutions, Thyssen Krupp, CCP Technology	Fraunhofer, Deutsches Zentrum Fuer Luft- Und Raumfahrt, Helmholtz-Zentrum Geesthacht Zentrum Fur Material- Und Kustenforschung
	Biological	3.2%	Thyssen Krupp, Robert Bosch, Evonik Degussa	Max-Planck-Gesellschaft, Forschungszentrum Jülich, Fraunhofer
	Photochemical and photocatalytic	3.0%	Evonik Degussa, Robert Bosch, Hydrogenious Technologies, Siemens, BASF	Helmholtz-Zentrum Berlin Fuer Materialien Und Energie, Friedrich-Alexander-Universitaet Erlangen-Nuernberg, Forschungszentrum Jülich

Technology area		IP output (% of global)	Leading companies	Leading non-profits and universities
	Thermal water splitting	8.9%	Siemens, CCP Technology, Robert Bosch, BASF, Silica Verfahrenstechnik	Fraunhofer, Deutsches Zentrum Fuer Luft- Und Raumfahrt, Technische Universitaet Bergakademie Freiberg
Storage and distribution	Compression and liquefaction	13.3%	Linde PLC, BMW, Daimler, Robert Bosch, Audi	Technische Universitaet Muenchen, Karlsruhe Institute ofTechnology
	Chemical storage	9.2%	BASF Se, Linde PLC, Hydrogenious Tech, Henkel Ag & Co., BMW	Friedrich-Alexander-Universitaet Erlangen-Nuernberg, Deutsches Zentrum Fuer Luft- Und Raumfahrt, Fraunhofer, Karlsruhe Institute of Technology
Utilisation	Gas blending	12.2%	Linde PLC, Siemens, Thyssenkrupp Industrial Solutions, Daimler, Bluecher	Forschungszentrum Jülich, Technische Universitaet Dresden, Leibniz Universitaet Hannover
	Transport	9.9%	BMW, Robert Bosch, Daimler, Linde PLC, Volkswagen	Ruhr-Universitaet Bochum, Karlsruhe Institute of Technology, Chemnitz University of Technology
	Electricity generation	2.6%	Siemens, Robert Bosch, Ez-Energies, Audi, BASF	Deutsches Zentrum Fuer Luft- Und Raumfahrt, Fraunhofer, Friedrich-Schiller-Universitaet Jena
	Industrial processes	3.2%	Siemens, Thyssenkrupp Industrial Solutions, Thyssenkrupp Uhde, BASF, Evonik Degussa	Fraunhofer, Universitaet Leipzig, Universitaet Siegen, Friedrich-Alexander-Universitaet Erlangen-Nuernberg

IP Australia patent analytics on hydrogen technology

IP Australia has developed an interactive visualisation tool to provide hydrogen insights to researchers, academics, business and policy sectors. For more hydrogen IP statistics including key destination markets, origin profiles, applicant profiles, collaborations and specific patent searches, refer to IP Australia's Hydrogen Patent Landscape tool:

- https://www.ipaustralia.gov.au/tools-resources/publications-reports/patent-analytics-hydrogen-technology

1.6.3 Project data

Data from the IEA Hydrogen Projects Database (as of October 2021)[164] provides insight on clean hydrogen technology value chains deployed at pilot and commercial scale across Germany. Note that the following limitations should be taken into account:

- The database does not indicate whether the technologies used are indigenous or purchased from an overseas provider. While many countries often deploy their own technologies at scale, many countries purchase technologies from overseas to deploy locally. As such the database indicates deployment activity, but not necessarily the ability to translate indigenous R&D into commercial scale-up.
- This dataset counts only low-carbon[165] hydrogen projects and their associated value chains. As such hydrogen production projects from gas, coal and oil without CCS are not included. Similarly, utilisation projects not related to a clean hydrogen project source are not included.
- The dataset reflects only projects occurring domestically, and therefore does not count projects undertaken by German companies outside of Germany. As such, the table may understate Germany's activity, particularly its contribution to international supply chain development. This data should therefore be considered holistically with the rest of this report.
- Any limitations stated in the data collection methodology, definitions and assumptions should be taken into account (see IEA Hydrogen Projects Database for details).

For the purposes of this report, the dataset has been filtered to include only projects from 2010 through to projects expected to be operational by 2030 as this timespan best reflects current activities. Projects without a specified date have been excluded from the table below. Further, only projects that are at feasibility study stage, final investment decision, demonstration, and operational are included. Projects at the 'concept' stage are not included. It should be noted that the majority of projects listed span production, storage and multiple end-uses, and as such can be counted in more than one technology category.

Table 16: Germany's domestic clean hydrogen project data

Technology	Sub-technology		Domestic project count	% of global
Production	Electrolysis	PEM	48	26.1
		Alkaline	27	23.3
		SOE	10	37.0
		Other or unspecified	21	8.5
	Fossil fuel conversion	Coal gasification with CCS	-	-
		Natural gas with CCS	-	-
		Oil with CCS	-	-
		Methane pyrolysis	1	100

[164] IEA (2021) Hydrogen Projects Database. Available at https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database

[165] IEA definition of low-carbon includes hydrogen production from renewables, fossil fuels with CCS, nuclear and biomass.

Technology	Sub-technology		Domestic project count	% of global
	Biomass and waste conversion		-	-
	Photochemical and photocatalytic		-	-
	Biological production		-	-
	Thermal water splitting		-	-
Storage & distribution	Compression and liquefaction		77	15.2
	Chemical carriers	Ammonia	-	-
		Methane	18	34.6
		Methanol	5	23.8
		Synfuels	3	30.0
Utilisation	Gas blending		37	27.6
	Transport		33	14.0
	Electricity generation		24	17.9
	Industrial processes	Refining	-	-
		Ammonia	-	-
		Methane	-	-
		Iron and steel	7	33.3
		Biofuels	-	-
		Synfuel	5	21.7
		Other industry	16	11.8

IEA Hydrogen Projects Database

The latest version of the IEA Hydrogen Projects Database can be found at:

- https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database

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