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ENERGY SECURITY IN GERMANY

An overview in the light of the challenges of 2022

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An overview in the light of the challenges of 2022

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Key Statements

Current geopolitical disruptions raise awareness that the diversification of energy supply chains is crucial for ensuring energy security in Europe. This includes (1) the diversification of energy (in particular natural gas and in perspective green hydrogen) suppliers, (2) the re-design of supply and recycling chains for critical raw materials with reliable partners and renewable energy technologies and (3) re-establishing vertically integrated value chains for sustainable technologies in Germany and Europe.

Energy security must go hand in hand with climate neutrality. This requires a significant acceleration of the implementation of green technologies in all sectors, a massive ramp-up of PV and wind, and a significant expansion of the grid. As the climate goals cannot be met with the current expansion strategy for renewable energy production, overhauling and harmonizing the regulatory framework will be essential.

Green hydrogen and its derivatives are expected to supply approximately 1/5 of the final energy worldwide in 2050. Through research and innovation Germany can strengthen its position as the technology leader in the field. Germany will rely on energy imports, in particular for H_2. This requires wisely selected strategic international partnerships with key countries and a reduction of dependencies with countries led by authoritarian governments in the long term. ↘Figure 1 summarizes the key elements for enhancing energy security in Germany.

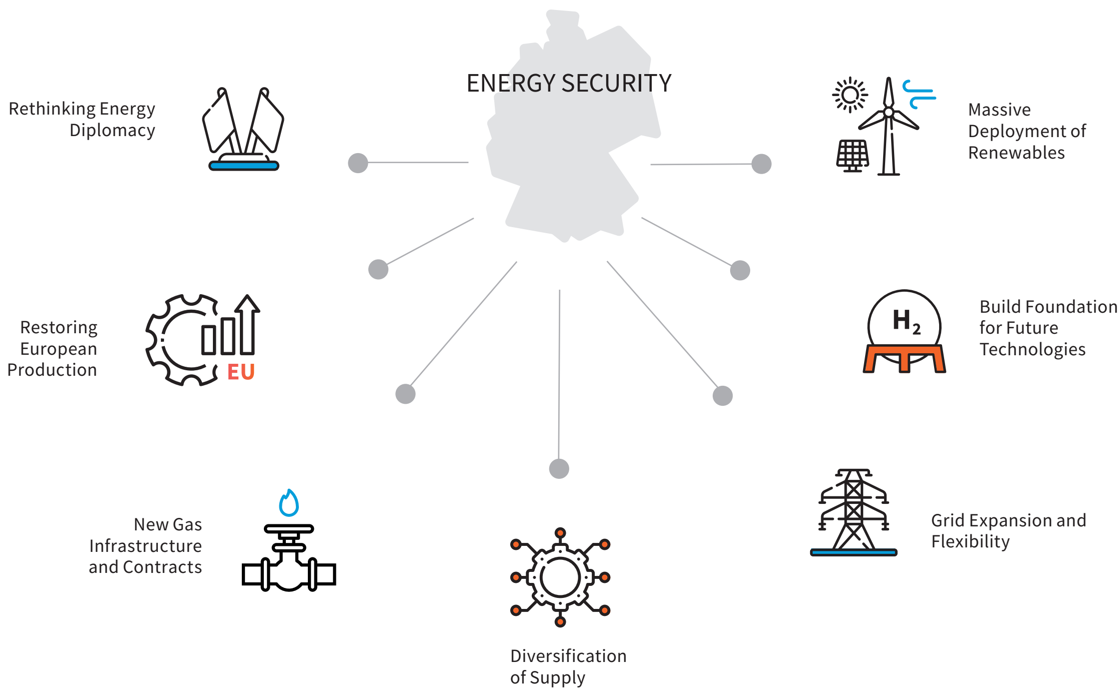


Figure 1: Key elements for enhancing Energy Security in Germany

1. Motivation

The rapid escalation of the climate crisis, the ongoing pandemic and the disruptive effects of Russia's unprovoked, unjustified war against Ukraine are leading to fundamental geopolitical and economic changes and a re-assessment of Germany´s and the European Union's energy policy and security.

In order to improve the resilience of the energy system in the short-, medium- and long-term, the EU plans to diversify the energy mix, energy fuels, sources and routes. The new geopolitical and energy market reality requires the EU to drastically accelerate the clean energy transition and increase Europe's energy independence from unreliable suppliers and volatile fossil fuels.

Measures to enhance energy security should be consistent with climate policy. The energy crisis cannot postpone the Climate Agenda as decisions in these areas are interdependent. The climate crisis aggravates the energy crisis and every decision that deviates from the intended climate goals brings irreversible climate change closer. For example, this year there is a significant reduction in the generation of hydro power plants due to the drought, which in turn leads to an increase in gas use for electricity generation, compared to last year. Drought also affects coal power plants (in terms of delivery) and nuclear power plants (in terms of water use in the production process). It is also affected the industry in terms of the delivery of raw materials and products due to low water levels in the rivers.

Successful achievement of climate goals requires a collective European effort based on joint commitments and solidarity. Electricity market integration across the EU Member States will be key to pursuing power sector decarbonisation at a lower cost.

This paper provides an overview of the current energy situation in Germany and Europe and highlights key measures for a successful energy transition in view of the global energy crisis.

2. Current Situation in Germany

The public net electricity generation in Germany in 2021 was 495 TWh (has increased by 2.5% compared to 2020 and approached pre-COVID 547 TWh in 2018) – thereof 228 TWh (46%; down from the 2020's 50%) was generated by renewables, 146 TWh (30%) by coal, 52 TWh (11%) by gas and 65 TWh (12%) by nuclear sources[1]. Despite the increase in power generation, the share of renewables in the power mix shrank in 2021 due to low wind power production, while coal power made a comeback. Coal power consumption increased noticeably, with both hard coal and lignite use increasing by about 24%. Therefore, the greenhouse gas emission rate in 2021 was higher than in 2020, and emission levels in 2022 are expected to be no less due to replacing gas-fired power plants with coal-fired power plants.

In the first half of 2022 public net electricity generation in Germany was 252 GWh, compared to 246 GWh in the first half of 2021. Renewables amounted to 130 GWh, or 51.8% (116 GWh or 47% in 2021); nuclear had a share of 16 GWh or 6.6% (32 GWh, 13% in 2021); gas amounted to 24 GWh or 9.4% (30 GWh, 12% in 2021); coal amounted to 78 GWh or 31% (compared to 66 GWh or 27% in 2021). In conclusion, renewable generation is increasing, while gas for electricity generation is replaced with coal.

The targets in the current EU and German policy documents did not consider Russia's sudden cut-off of energy supplies. The need to replace such energy resources is a key challenge to meeting the targets, including achieving climate neutrality.

In 2021, fossil fuels provide almost 80% of Germany's total primary energy demand. Germany's dependence on Russia was significant: 55% of gas, 34% of oil, and 53% of hard coal were provided by Russia.

Since diversification is one of the key measures to strengthen energy security, Germany should be fully aware of where else we may have weaknesses in terms of the supply of energy, raw materials, and products.

As to oil, the U.S. provided 12.5%, Kazakhstan 9.8% and Norway 9.6%. In total, 30 countries provided crude oil to Germany, ensuring a rather diversified supply. Besides Russia, coal supplies include the United States (18.3%) and Australia (12.3%)[2]. Renewable technologies and batteries require certain metals for their production, such as cobalt, lithium, and rare earth elements. China has mining access to and is the main global supplier of two-thirds of critical materials for the industry[3]. Germany will have to rethink its energy diplomacy, and, in some areas, this should be done in advance, in particular with regard to supply chains of renewable energy-related goods and technologies.

1 Public net electricity generation in Germany in 2021. Energy-charts. info
2 Clean Energy Wire
3 Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study

3. Key Challenges for the Energy System

The transition to a sustainable economy necessitates the use of green energy, with photovoltaics and wind becoming the main pillars. Hence this green transformation is going to hinge on the generation of green electricity and its storage and conversion into H_2-based fuels and chemicals in the long-term perspective. The dominant role of PV and wind energy is reflected in the current goals of the German government.

Germany's main climate policy milestones include a reduction of 65% in greenhouse gas emissions by 2030, 77% by 2035, 90% by 2040 and reaching greenhouse-gas neutrality by 2045. Along with 80% of renewables in the power mix by 2030, with specific goals of the German government for an installed capacity of 215 GW of solar, 115 GW of onshore wind and 30 GW of offshore wind (↘ Figure 2a).

If Germany successfully fulfils the plans, electricity generation from renewable energy will be 352 TWh already in 2025 (in 2021 it was 228 TWh) and in 2035 net electricity generation from renewables will be 845 TWh[4] (↘ Figure 2b).

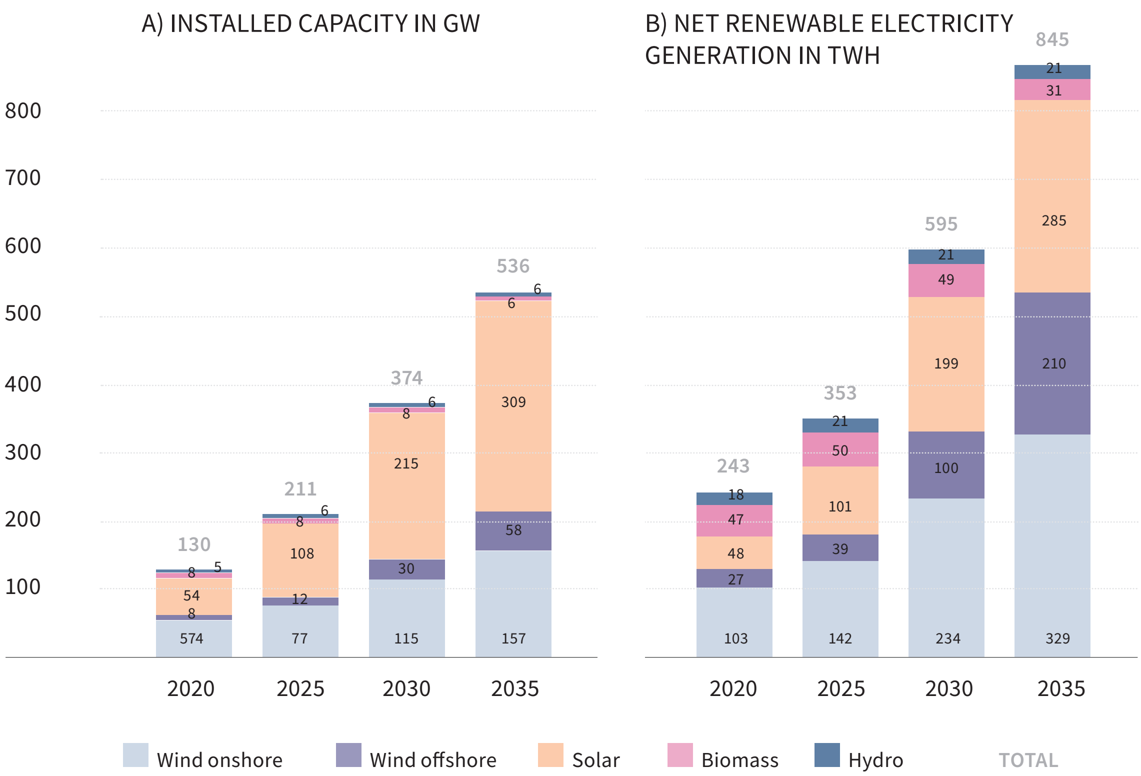


Figure 2(a) and 2(b): Illustration of the projected installed renewable capacity and projected net renewable electricity generation[4].

4 Agora Energiewende, Prognos AG, Consentec GmbH (2022). Klimaneutrales Stromsystem 2035

The level of future electricity demand is a key driver for the necessary expansion of renewable energies and the electricity system as a whole. According to Agora Energiewende's study "Climate neutral power system 2035" from August 2022 the increasing electrification of industry, transport and buildings, as well as hydrogen production, will raise the electricity consumption to around 725 TWh by 2030 (↘Figure 3). The electrification of these sectors significantly reduces German greenhouse gas emissions in a climate-neutral electricity system.

GROSS ELECTRICITY CONSUMPTION, TWH

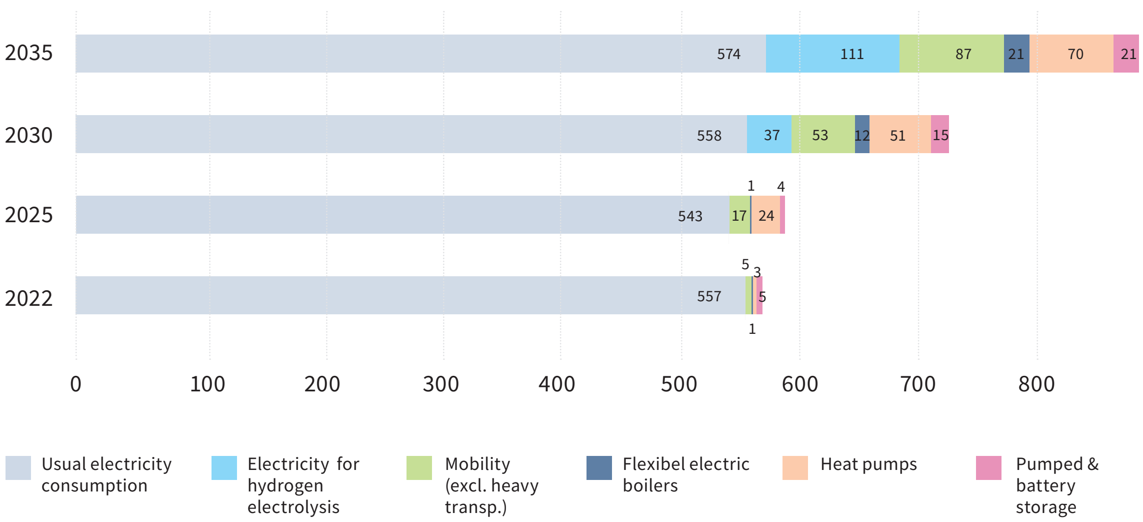


Figure 3: Projected gross electricity consumption in Germany[4]

Ambitious goals require massive actions. And today Germany must act not only in accordance with its adopted plans but also in response to the challenges of the global energy crisis. Along the way, Germany has to review its energy policy of recent decades and learn lessons for the future. The most pressing issue in the short term is the substitution of Russian natural gas with alternative gas resources. In the medium term, a massive deployment of renewable capacities must be realized, while ensuring grid flexibility. Third, Germany has to build the foundations for the integration of H_2 as a key element for the energy transition, in order to establish a fully operational hydrogen economy as a prerequisite for industry emissions reduction, especially in hard-to-abate sectors in the long term. Last but not least, there is the challenge of diversification of (1) energy, (2) raw materials, (3) products and technologies (creation of the domestic value chains or being a part of existing ones), and (4) suppliers with preference to the partnerships with shared democratic values and governing traditions. And here there is high competition in the world for reliable, long-time contracts.

Leaders in technological innovation are positioned to gain the most from the global energy transformation[5]. This represents an opportunity for Germany to become a technology leader in the hydrogen industry.

5 International Renewable Energy Agency (IRENA), 2019. A New World. The Geopolitics of the Energy Transformation.

4. Measures to enhance Energy Security

All measures below are arranged from short-term to long-term and are divided to into three basic categories: (1) measures to reduce or/and electrify demand, (2) measures to increase the flexibility of the electricity system and (3) measures that are needed to create preconditions for the deployment of new technologies in the future. Paths with an existing value chain are most feasible to implement; paths based on emerging technologies require substantial financial, social and political support. Innovation and technology development are key drivers of fulfilling the measures.

4.1 Natural gas

Since gas will remain one of the prominent energy sources in Germany, the first measure would be to replace the gas counterparty. With lessons learned there should be different parties from different reliable countries with various routes of supply. The next step is new infrastructure – LNG terminals and new pipelines (with the possibility of future repurposing). The measures below are aimed at reducing demand and deployment of new technologies.

Fill up pump gas storage

As of 27.11.2022 gas storage load level is 98 %[6]. This year Germany has successfully prepared gas reserves for the upcoming winter: stricter storage requirements, existing gas flows from Russia delivered by pipeline in the first half of the year, and lower-than-expected LNG demand in China, contributed to this development. The preparation for the next winter is going to be more difficult in terms of gas sources and prices and partly destroyed infrastructure.

Implement saving measures

The European Commission presented the “Save gas for a safe winter” Plan on 20.07.2022. It requires a voluntary reduction of natural gas demand by at least 15 % from 1 August 2022 until 31 March 2023 compared to the average consumption in the same period during the 5 consecutive years preceding the entry into the force of the proposed Regulation. Mandatory natural gas demand reduction by at least 15 % in case of the “Union alert”. Germany increased targets of reducing gas consumption by 20 % from August 2022 to March 2023.

The European Commission’s proposals for enhancing solidarity through better coordination of gas purchases, exchanges of gas across borders and reliable price benchmarks were made in October 2022. The proposal entails the aggregation of EU demand and joint gas purchasing to

6 Gas storages data available at https://agsi.gie.eu/

negotiate better prices and avoid competition between the Member States (MS) on the global market; the creation of a new LNG pricing benchmark by March 2023, and in the short term proposing a price correction mechanism; default solidarity rules between MS in case of supply shortages, extending this rule to those MS without direct pipeline connection to involve also those with LNG facilities; and a proposal to create a mechanism for gas allocation for the Member States affected by a regional or Union gas supply emergency.

Replace gas in power generation

Re-starting some of the coal-fired power stations set for decommissioning. Coal-fired plants must be ready to start quickly in case of a shortage of gas from other suppliers and a shortage of capacity for power generation in Germany. Hard coal is not produced in Germany anymore. Lignite is a fully domestic energy source that is used mainly for baseload electricity generation (with the disadvantage of high CO_2 emissions per kWh). The forced coal comeback should be mitigated with CCUS (carbon capture utilisation storage).

LNG contracts

Direct natural gas deliveries to Germany by pipeline could not be expanded in the short term. In February, established suppliers such as Norway and the Netherlands indicated that a substantial supply volume expansion is not impossible. So, LNG contracts are the option. LNG imports 25% of the EU gas supply. In the EU last year only France and Poland signed long-term (20 years) LNG contracts. This year Slovakia has signed an LNG contract (with U.S. and negotiations continue with Qatar Energy and Sempra). Germany has signed its first LNG contract with the United Arab Emirates. The first shipment is to arrive at the new LNG terminal in Brunsbüttel near Hamburg in December 2022. According to RWE, a memorandum was signed for multi-year deliveries starting in 2023. Likewise, Uniper signed a flexible long-term sale and purchase agreement with Singapore's Woodside Energy to supply LNG from January 2023 up to 2039. Additionally, the 15-year sale and purchase agreement is signed between QatarEnergy and US' ConocoPhilips regarding the delivery of LNG to Germany from 2026. Earlier in October Qatar announced an increase in its LNG production by 64% by 2027.

Build LNG infrastructure

Currently, there are 22 operational LNG terminals in Europe[7], onshore and FSRU [FSPU – Floating Storage and Regasification Unit]. Until this year, there were no LNG terminals in Germany, LNG must be procured mainly via terminals in Belgium (Zeebrugge), France (Dunkirk) and the Netherlands.

Germany is developing 5 LNG terminals (FSRU): in Wilhelmshaven; in Brunsbüttel; also in Stade and Lubmin. The first two were scheduled to begin operations as early as this winter; the rest will be ready for operation until the end of 2023. A private consortium will build the sixth terminal in

7 LNG Import Terminals Map Database October 2022; Gas Infrastructure Europe site.

Lubmin by the end of the year. In 194 days Germany completed its first floating LNG terminal in Wilhelmshaven. It can regasify a minimum of 5 bcm of LNG annually, with a maximum capacity of 7.5 bcm. A second FSRU is expected in late December.

To accelerate the construction of LNG infrastructure, the LNG Acceleration Act was adopted in May 2022. The law simplified the authorisation procedures for LNG terminals and related facilities. The approvals for the LNG facilities are to be limited in duration to no later than 31 December 2043. It is assumed that continued operation of these facilities will only be possible after that point if they are used for climate-neutral hydrogen and its derivatives.

Build new gas pipelines

Germany will consider the potential benefits of the new construction of the Trans-Saharan gas pipeline. Joint action plan about the new Pyrenean gas pipeline agreed upon between Germany and Spain.

Develop carbon-neutral LNG (CN-LNG)

LNG terminals could be updated and repurposed for liquefied low-carbon commodities and thus be part of the solution in reaching climate goals. There are several decarbonisation pathways, some of them are feasible with the existing infrastructure: via bio-LNG, syLNG; other low-carbon commodities (methane reforming, pyrolysis); some of them require to be updated or special conditions: hydrogen carriers (LOCH, ammonia and liquid hydrogen – last two options of low feasibility due to special required conditions); e-fuels.

Integrate new natural gas capacities

Manoeuvring power plants. Pumped storage power plants. New gas plants at first will work on natural gas, but they must be able to run on 100 % hydrogen in the coming years. Their construction must be ensured. Agora Energiewende’s study predicts that the use of hydrogen for electricity generation will begin in Germany in 2024 when the first projects enter the operational phase. The use of hydrogen as a fuel for gas-fired power plants will increase from 12 % in 2030 to at least 75 % in 2035[8].

Roll out heat pumps

Gas will remain important in the heating market for many years to come. The main task here is to reduce demand to the possible extent and to switch to electricity. The solutions will be expensive and, therefore, support measures will be needed for both industry and consumers for the next few years. For new buildings, electric heat pumps are now the most important heating technology, which requires subsidies.

8 Agora Energiewende, Prognos AG, Consentec GmbH (2022). Klimaneutrales Stromsystem 2035.

Encouragement measures for residential heat pumps combined with a gradual ban on fossil fuel boilers (as of 01.01.2024 newly installed heaters must run on 65 % renewables) contribute to the goal of increasing the number of heat pumps installed from 2024 up to 500,000 per year. Heat pumps offer additional demand-side flexibility, provided that the vast majority of the nearly nine million heat pumps in 2035 can be controlled via software interfaces. To accelerate the roll-out of heat pumps the European Commission made a proposal to temporarily (for one year period) speed up a permitting process – it shall not exceed 3 months. The decision concerns heat pumps of a small capacity of up to 50 KW. In Germany, there are subsidies for heat pump purchases in the building sector.

The European Commission has approved a € 2.98 bn for Germany to promote green district heating based on renewable energy and waste heat until 30 August 2028. The aid will take the form of direct grants, it is expected to support the installation of approximately 681 MW / year of renewable heat generation capacity. The scheme is open to district heating network operators.

Subsidize industrial consumers and energy companies

Germany's energy-intensive industries, steel and chemicals, will receive from the EU €5 billion of subsidies with permission of the EU's competition authority.

The European Commission approves aid amounting to 225.6 million euros for Germany to take 100 % ownership of SEFE (Securing Energy for Europe, former Gasprom Germany) to support the company and secure gas supply. Besides, the German Government bailed out Juniper.

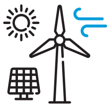
The German government established the Expert Commission on Gas to set up a list of measures, applicable from 31.01.2023 till 30.04.2024 within a € 200 billion relief package. Among proposed measures were a one-time payment for consumers in December 2022 to cover one month's gas bill; monetary incentives to save gas: 80 % of normal gas consumption will be subsidised for households; for the industry: 70 %; pushing gas out of electricity generation µ gas power plants will not be subsidised.

The first support measures come in the amount of € 99 billion, split between € 56 billion for gas and district heat and € 43 billion for electricity. To finance these measures a tax on the "windfall profits" of energy companies will be applied from 1 December until 30 June with a possible extension until April 2024. To calculate tax amount, production costs of coal and nuclear power plants will be compared to hourly electricity prices, accounting for the company's existing hedge or forward contracts; for renewable power plants monthly average will be used. The tax will be in the amount of 90 % of the "windfall profits".

Expand Power-to-heat technology

Power-to-heat technology is a flexibility option for integrating electricity into heat applications (industry, local heating, district heating, etc.). As an example, Swedish Vattenfall is building

Europe's largest heat storage facility with 56 million litres capacity at the 600 MW coal-fired power plant in Berlin. It can provide heat for about 13 hours. If a surplus of wind energy is available, it can be converted on-site via a power-to-heat system and stored in the buffer. The system is scheduled to go into operation in April 2023. The Agora Energiewende study[9] study predicts that the installed capacity of power-to-heat plants is 10 GW in 2030 and 20 GW in 20357.



4.2 Renewables deployment

Accelerating the transition toward a carbon-neutral economy is essential for reducing the dependency on fossil energy supply. Approved large-scale deployment of renewable capacity requires systematic (80 % of renewables in the power mix by 2030 with the current 46 %), persistent work on (1) capacity building and (2) parallel grid expansion and (3) deployment of solutions for grid integration in line with hydrogen development plans.

Increase capacity

In 2035 net electricity generation from renewables is expected to be 845 TWh (in 2021 it was 221 TWh)[9]. This 624 TWh increase from 2021 to 2035 translates into the installation of a renewable energy capacity of approximately 500 GW.

INSTALLED PV CAPACITY IN GERMANY IN 2021 – 2022, MW

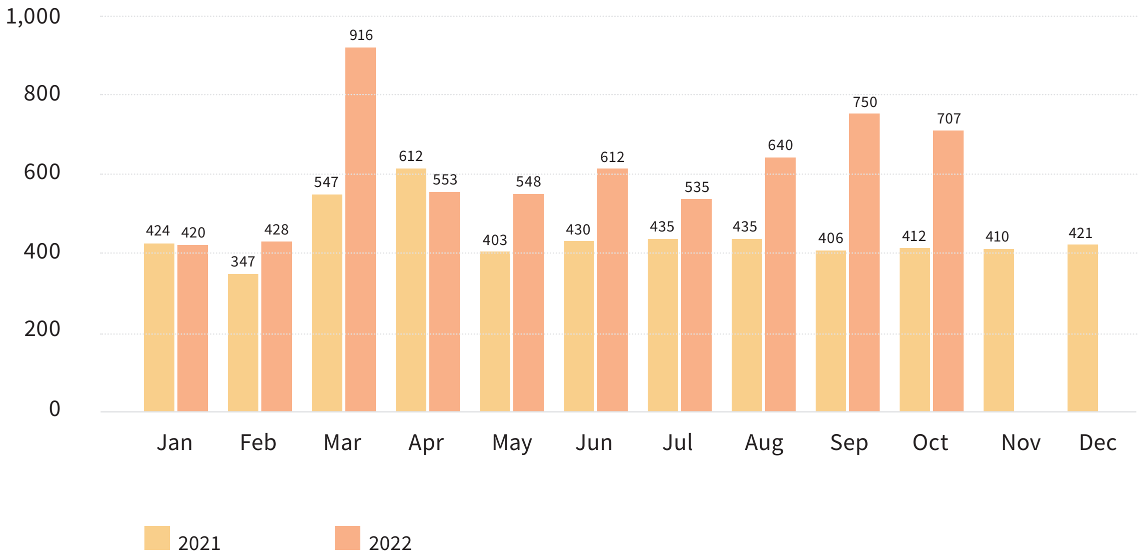


Figure 4(a): Illustration of the monthly installed new capacities in 2021 – 2022[10]

9 Agora Energiewende, Prognos AG, Consentec GmbH (2022). Klimaneutrales Stromsystem 2035.
10 pv-magazine.de

As for now, the pace of commissioning new capacity is insufficient (↘Figure 4a, 4b). In order to add 215 GW of solar installed capacity by 2030, on average 1.5 GW per month have to be installed, concerning onshore wind – around 0.6 GW[11]. This would be a drastic increase from 5.3 GW of solar and 1,9 GW of onshore wind capacities having been installed in the whole year 2021 and requires tripling the monthly solar installation and doubling the wind onshore installation.

INSTALLED ONSHORE WIND CAPACITY IN GERMANY IN 2021 – 2022, MW

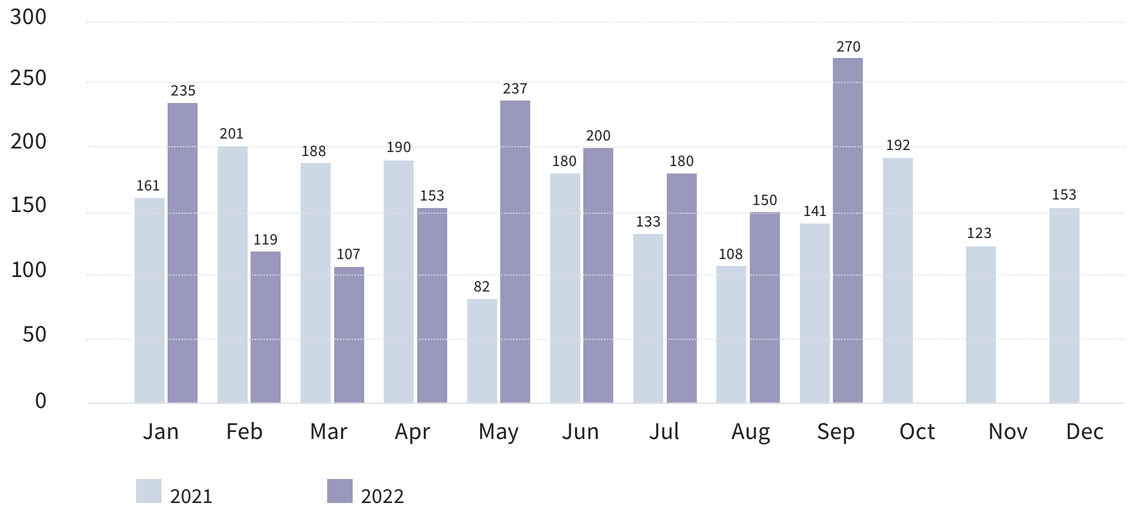


Figure 4(b). Illustration of the monthly installed new capacities in 2021– 2022; energy-charts.info

At predicted rates of deployment, only four out of 27 EU countries (Finland, Croatia, Lithuania and Sweden) will achieve sufficiently high annual wind capacity increases to align with 1.5C. The EU as a whole is also not on track for required solar deployment rates[12]. Nevertheless, The European Union's additional renewable capacity is set to more than double in 2022, up to 50 GW.

Regulations have to set a paradigm shift for the swift expansion of renewables

Photovoltaics systems with a capacity of 215 GW take up an area of approximately 2150 km^2, which corresponds to roughly 2.5 times the size of the Berlin area[11]. This can only be reached if solar panels will be mandatory on all new buildings, the potential of agricultural land will be exploited and building-integrated PV will be promoted. This requires promoting PV installations and harmonizing the legal basis for consistent regulations.

11 Own estimations

12 Ready, Set, Go: Europe's race for wind and solar. Ember report. July 2022.

The potential for agriculture corresponds to 1.2 TWp, the building envelope to 1 TWp, covered parking spaces 59 GWp, and sealed settlement areas (without buildings and traffic areas such as roads or railways) 134 GWp[13].

The installation of offshore wind turbines with a capacity of 50 GW will require the installation of 5000 to 10 000 offshore wind turbines at 5–10 MW each[10]. This can be realised if all currently usable areas in the German North Sea and Baltic Sea will be developed[14].

The installation of 100 GW requires 20 000 onshore wind turbines at 5 MW each. In comparison from Jan-May 2022, merely 100 new wind turbines were commissioned (407 MW). According to the Coalition Agreement, 2% of the national land area could be taken for onshore wind power generation. So far, only about 0.5% of Germany’s land area is available for onshore wind turbines. The new “Onshore Wind Energy Act” will set binding area targets for lands.

The European Commission proposed to address the permitting process as one of the bottlenecks of the deployment of renewables. Thus, a maximum deadline of one month is proposed for the permitting process for solar energy equipment and its co-located storage and grid connections when it is not installed on natural ground. For the repowering projects the new maximum deadline of six months and simplified procedure for grid connections in cases where the repowering doesn’t exceed a 15% increase in total capacity compared to the original project[15].

Minimize dependencies on non-European suppliers by restoring European production

In 2020, producers from Asia amount to 95% of total c-Si PV module production. China holds the lead with a share of 67%. Europe contributed a share of 3%; USA/CAN 2%[16]. In this situation, a massive development of renewable energy could lead to an increase in Europe´s dependence on supplies of both equipment and raw materials.

13 Recent Facts about Photovoltaics in Germany. Fraunhofer ISE. May 2021
14 Energiewirtschaftliche Bedeutung der Offshore-Windenergie für die Energiewende. Fraunhofer IWES, 2017
15 REPowerEU: Commission steps up green transition away from Russian gas by accelerating renewables permitting. Press reliese. November 2022.
16 Photovoltaics report. Fraunhofer ISE, 2022.

↘ Figure 5 below illustrated Asian domination within the PV supply chain:

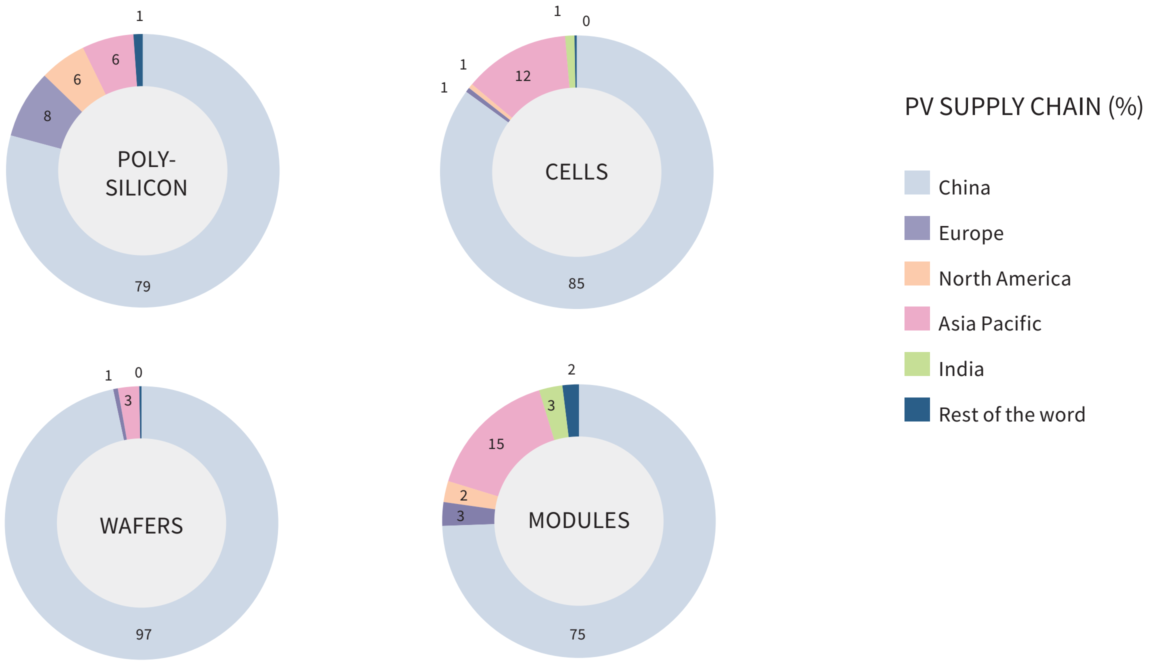


Figure 5: Share of manufacturing capacity by country / region in 2021[17]

European manufacturing could (1) guarantee a reliable constant supply within the country/continent to meet the expectations of a huge domestic market in the following years *(The REPowerEU proposal aims for the EU to reach 1236 GW of renewable capacity by 2030, up from 513 GW of installed capacity in 2021);* (2) diversify supply and reduce supply chain vulnerabilities; (3) create and secure jobs; (4) sustainable development of production processes in line with a circular economy.

The potential for rapid development of PV industry in Europe is tremendous, considering the strong PV research (e.g. world records in Perovskite technology reaching more than 30% efficiency) and the know-how in Germany and Europe. Fostering industry/manufacturing together with accompanying research on multi-GWp[18] brings about targeted sovereignty.

Since the German economy is dependent both on the export of its products and on the import of energy and raw materials and energy-related products (e.g. PV panels), the resumption of European production will be of great importance considering the Energy Transition. High-tech products will be both produced and consumed domestically, increasing the country's independence.

17 Special Report on Solar PV Global Supply Chains, IEA, July 2022
18 European Technology and Innovation Platform for Photovoltaics (ETIP PV), 2022. Strategic Research and Innovation Agenda on Photovoltaics (SRIA).

Moreover, since the COVID pandemic and now, in light of the Russian war against Ukraine, there is an emerging trend of shifting from globalization to deglobalization, transition from global cooperation, and production of large corporations to local.

Recruit and educate skilled workforce

According to a study by EuPD Research, an annual expansion of 10 GW of PV requires almost 70,000 full-time direct employees, with a focus on installation and maintenance. Additionally, the solar PV industry could create 1300 manufacturing jobs for each gigawatt of production capacity[19]. The German PV Industry employed around 51,000 people in 2021[20].

There is a shortage of qualified workers, especially concerning the installation of the equipment. This problem will only worsen over time without the necessary decisions being taken today. Tailored educational programs, the possibility of re-qualification; economic incentives, and promotional campaigns have to be set in place today to establish a workforce for PV and wind.

Repower existing wind turbines

Germany will increasingly be faced with the need to replace old power plants (both solar and wind). According to the Fraunhofer ISE research, this could amount to 17 GW per year[21]. In the first half of 2022, 82 wind turbines with a combined capacity of 99 MW were decommissioned[22] and 133 MW were repowering.

Germany could benefit from upgrading/repowering existing power plants in terms of installing recent equipment with higher efficiency. And thus improve the efficiency of the use of land already allocated to the energy sector.

Expand and integrate the electricity grid

Grid expansion and improved interconnection (both transmission and distribution) are essential for accommodating the increasing amount of renewable energy. Smart sector integration while network planning (smart grid and metering) are required. For grid flexibility digital grid solutions and flexible grid assets (FACTS) are needed.

Electricity grids as the most essential part of the future energy system should be planned at the EU level. Given the share of renewables in the German power mix and existing plans to increase the renewable share significantly, it is in Germany's interest to participate in the European Union's electricity grid development planning, which will guarantee the free transfer of excess generation to other EU countries.

19 International Energy Agency (IEA), 2022. Solar PV Global Supply Chains. Special report.
20 BSW 2022
21 Recent Facts about Photovoltaics in Germany. Fraunhofer ISE. May 2021
22 Status of Onshore Wind Energy Development in Germany. I half of 2022. Deutsche WindGuard.

More than 15 % of Europe's power is traded between countries in a typical year, making it the world's most interdependent region in terms of electricity[23], so electricity flow across borders is crucial. The benefits of cross-border electricity trade are estimated at €34 bn a year[24].

Overhaul supply chains of raw materials

The European Union has identified 30 raw materials as critical for the industry. China has mining access to and is the main global supplier of two-thirds[25]. The European Commission announced the Critical Raw Materials Act. A harmonized approach to creating a level playing field within the EU is necessary. This is important, as critical raw materials influence not only the ability to cater for rapidly increasing demand while Energy Transition but its price as well.

Germany has to consider being part of various value chains and entering long-term supply contracts while ramping up its own production and aiming at replacing critical materials with abundant components through technological advances.

It was calculated[26] that by 2050, the Green Deal alone will increase demand for aluminium by 33 %, copper by 35 %, zinc by 11 %, nickel by 103 %, cobalt by 331 %, and lithium by as much as 3535 %. For the base metals aluminium, copper and zinc, the increased demand can still only be partially met (45 – 65 %) by higher recycling efforts. European demand for rare earths alone will increase fivefold by 2030 on the way to achieving the Green Deal goals. *"Lithium and rare earths will soon be more important than oil and gas,"* Ursula von der Leyen emphasized.

↘ Figures 6 (a–e) Illustrated key regions of the world's reserves of critical materials and their manufacturing and reveal their concentration.[27]

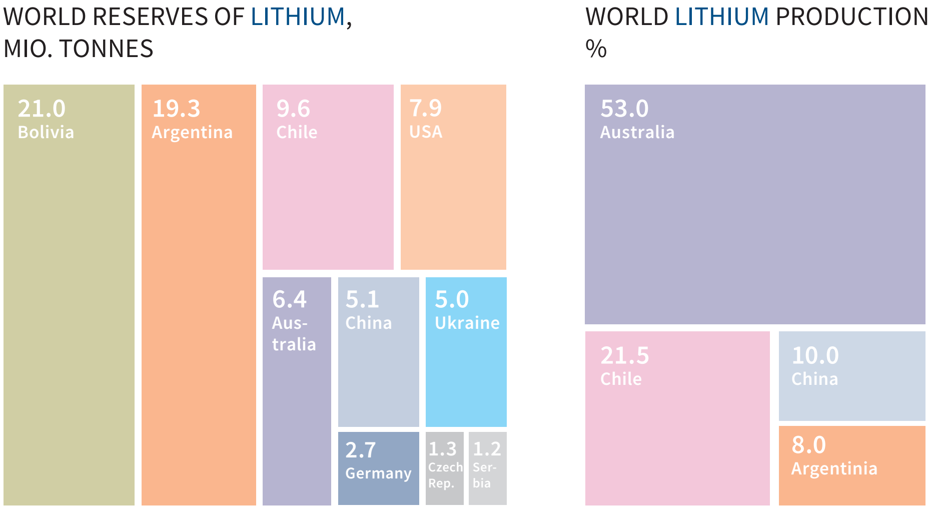


Figure 6a: World Lithium reserves and top 5 countries in Lithium production.

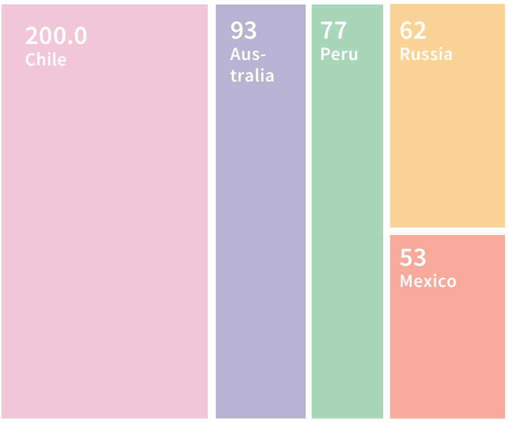
23 Can Europe keep the lights on? Financial Times, November 2022
24 ACER's Final Assessment of the EU Wholesale Electricity Market Design, April 2022
25 Critical Raw Materials for Strategic Technologies and Sectors in the EU. A Foresight Study.
26 Metals for Clean Energy: Pathways to solving Europe's raw materials challenge, April 2022
27 Based on IEA's World Energy outook 2022; Investing News Network website investingnews.com

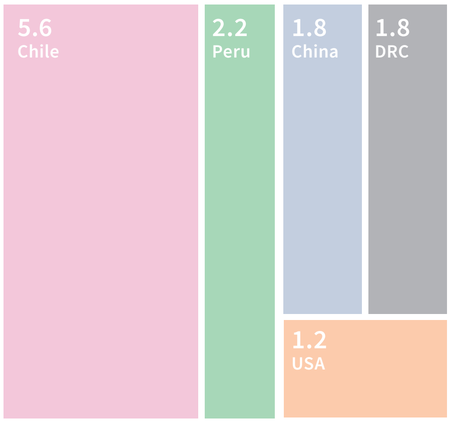
Almost all large lithium deposits are controlled by several mining companies with market capitalizations ranging from $5 billion to $70 billion: Chinese Jiangxi Ganfeng and Tianqi, Argentina's FMC, America's Albemarle, Chile's SQM .

TOP 5 COUNTRIES WITH WORLD RESERVES, MIO. METRIC TONNES

TOP 5 COUNTRIES – PRODUCERS, MIO. METRIC TONNES PER YEAR

COPPER





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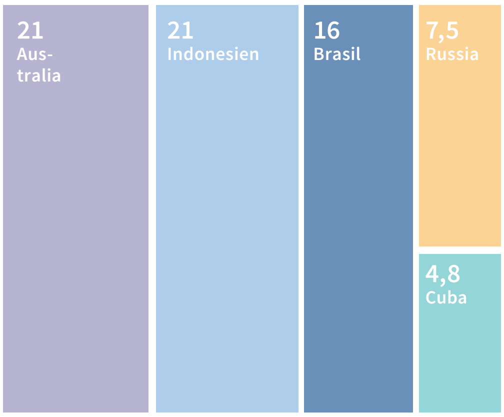
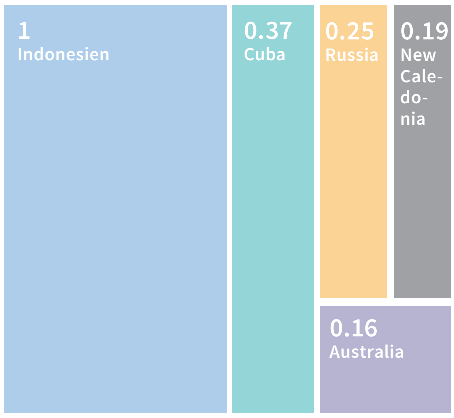
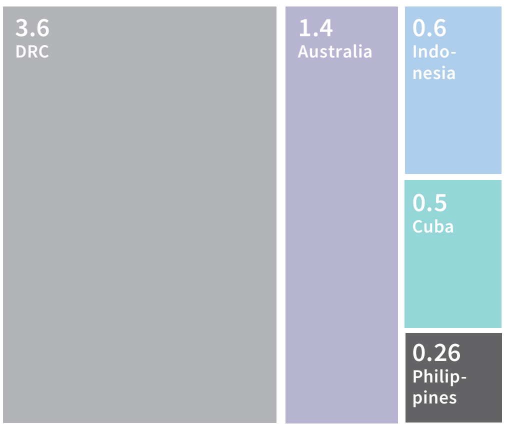
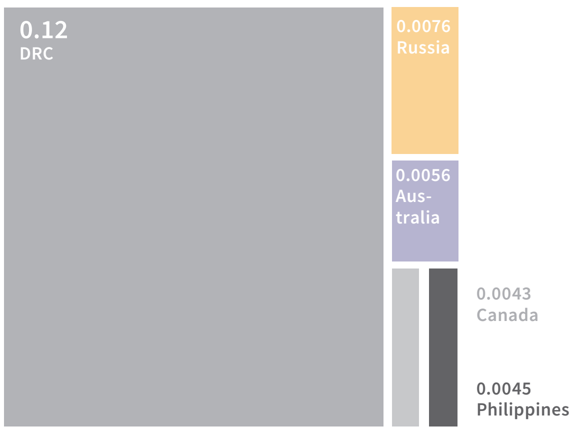




COBALT

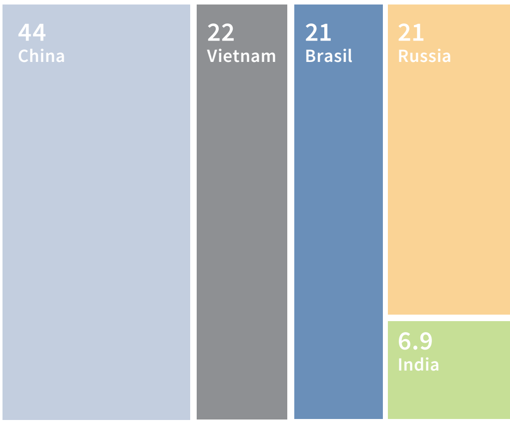




TOP 5 COUNTRIES WITH WORLD RESERVES, MIO. METRIC TONNES

TOP 5 COUNTRIES – PRODUCERS, MIO. METRIC TONNES

RARE EARTH



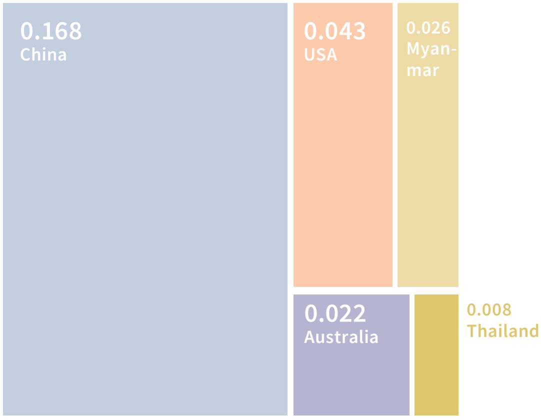


Figure 6 (b – e): Top 5 countries in world reserves of selected materials and top 5 countries in their production.

Renewables could and should create new trade routes. Some minerals can also be recycled, and re-used, thereby further reducing their perceived scarcity.

Circular Economy and Recycling

The circular economy involves reusing, repairing, refurbishing and recycling existing materials and products to keep materials within the economy wherever possible.

All stages of the European value chain – mining, refining, processing and recycling – are to be strengthened, with a particular focus on the recycling stage. In light of the above consideration, recycling become a very important line of activity and there is a need for R&I projects in this area and policy development for the goals of the circular economy.

Germany is planning its Circular Economy Strategy. Before that, there will be a broad dialogue with scientific participation. This is a matter of high importance in the face of rising raw materials prices during the Energy Transition.

4.3 Hydrogen and green hydrogen derivatives

Hydrogen is a key element for the Energy Transition and achieving climate goals. Hydrogen can help achieve a significant reduction in CO_2 emission in multiple sectors and is the only viable option for hard-to-abate sectors.

Secure hydrogen supply

According to the German National Hydrogen Strategy[28] around 90 to 110 TWh of hydrogen will be needed by 2030; this corresponds to an electrolysis capacity of about 40 GW. Germany plans to establish up to 10 GW of generation capacity including offshore and onshore energy generation facilities (5 GW by 2030, which roughly corresponds to 14 TWh of green hydrogen production and will require 20 TWh of renewables-based electricity; 5 GW to be added by 2035, no later than 2040).

There is a supply gap of 30 GW of installed electrolysis capacity. Since the hydrogen demand cannot be met by domestic production, most of the hydrogen needed will have to be imported from e.g. the European Member States, bordering the North and Baltic Sea, and countries of Southern Europe.

In 2045 Germany is expected to need 265 TWh of hydrogen[29] (current demand around 55 TWh; produced from fossil energy sources), only 36 % of which will be produced in Germany. This means that Germany needs to import most of the required volume of green hydrogen from other countries. Most recent calculations that fully consider the decarbonization of hard-to-abate sectors predict that the total demand for hydrogen as well as other synthetic fuels and feedstocks in 2045 is expected to be 422 TWh[28], of which 326 TWh must be imported (↘Figure 7).

H2 DEMAND IN GERMANY, TWH

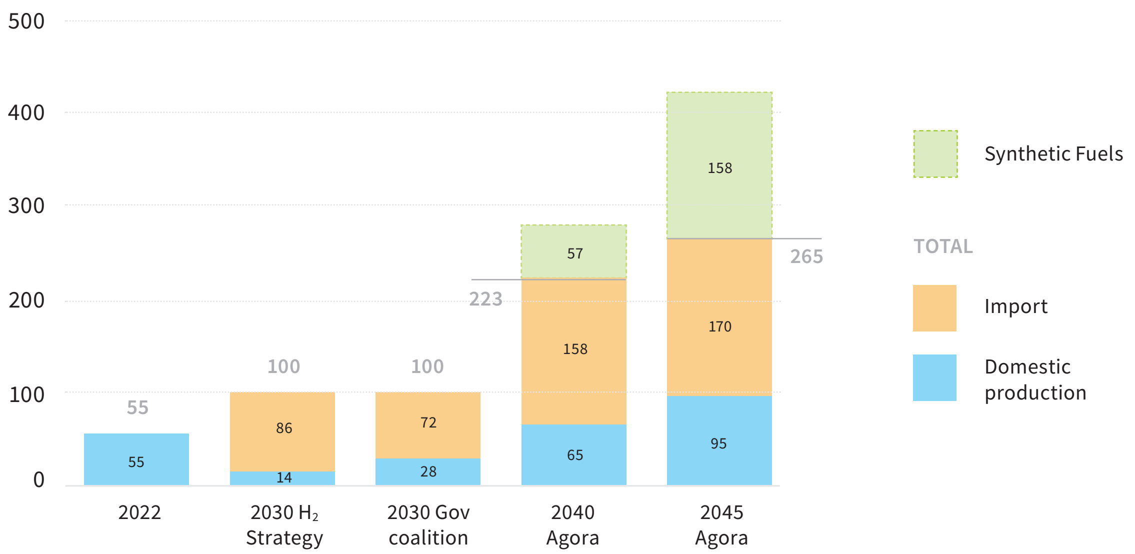


Figure 7: Forecasted demand for hydrogen in Germany[27,28].

28 The National Hydrogen Strategy, Federal Ministry for Economic Affairs and Energy, June 2020.
29 Agora Energiewende, Stiftung Klimaneutralität, Prognos AG, Öko-Institut e. V., Wuppertal Institut für Klima (2021). Towards a Climate-Neutral Germany by 2045. How Germany can reach its climate targets before 2050

Develop technological H_2 solutions for hard-to-abate sectors

No-regret applications for hydrogen are in the energy intensive industrial sector (steel, chemical, refinery); transport (aviation, shipping, trucks, buses) and power sector (storage). Germany's industrial sector is well-placed to become one of the main factors speeding up the market rollout of hydrogen and a global pioneer for hydrogen technology: Hydrogen and hydrogen-based PtX commodities need to be used to drive forward the decarbonization of emission-intensive industrial processes.

Develop a market-based infrastructure and transportation system

The hydrogen infrastructure will play a central role in the timely development of a market-based and competitively organized hydrogen economy. There are two transportation options for hydrogen:

- Pipelines – either new or repurposed existing – to transport pure compressed gaseous hydrogen, hydrogen blended into the methane network or hydrogen converted into ammonia, methanol or liquid organic hydrogen carrier (LOHC);

- Shipping (maritime and land): either as a liquid following cooling to temperatures below –252°C, or in ammonia, methanol or a LOHC.

The necessary conversion process is energy and cost-intensive and makes up a significant part of the total costs.

According to Wood Mackenzie, more than 85% of export-oriented hydrogen supply projects involve ammonia production[30]. At the same time, ammonia is intended for export markets, while hydrogen is mainly intended for domestic markets. The Hydrogen transportation cost is mainly dependent on the size of the project and the transporting distance. Distance is more critical for pipelines since their costs are directly proportional to distance, while for shipping, 70–90% of the total cost is allocated in the terminals (plants and storage)[31].

There are two main approaches to the transportation of green hydrogen:
First, the proposed European Hydrogen backbone initiative – pipeline network through five supply corridors (North Africa & Southern Europe; Southwest Europe & North Africa; the North Sea; Nordic and Baltic regions; East and South-East Europe)[32].

Second, the no-regret vision states that the hydrogen infrastructure will develop around demand clusters. Four such "no-regret" corridors were identified in total: in Central-West Europe, East

30 Wood Mackenzie Hydrogen Project Tracker
31 International Renewable Energy Agency (IRENA), 2022. Global hydrogen trade to meet the 1.5°C climate goal: Part II – Technology review of hydrogen carriers.
32 Wang, A., van der Leun, K., Peters, D. and Buseman, M., 2020. European Hydrogen Backbone.

Europe, Spain and South-East Europe[33]. ENTSO-G's map of current H_2 projects shows that existing projects are located closer to the demand, than to the cheap green electricity sources[34] (↘ Figure 8):

Hydrogen will be transported by pipelines up to medium distances within and between countries, but almost never between continents[35].

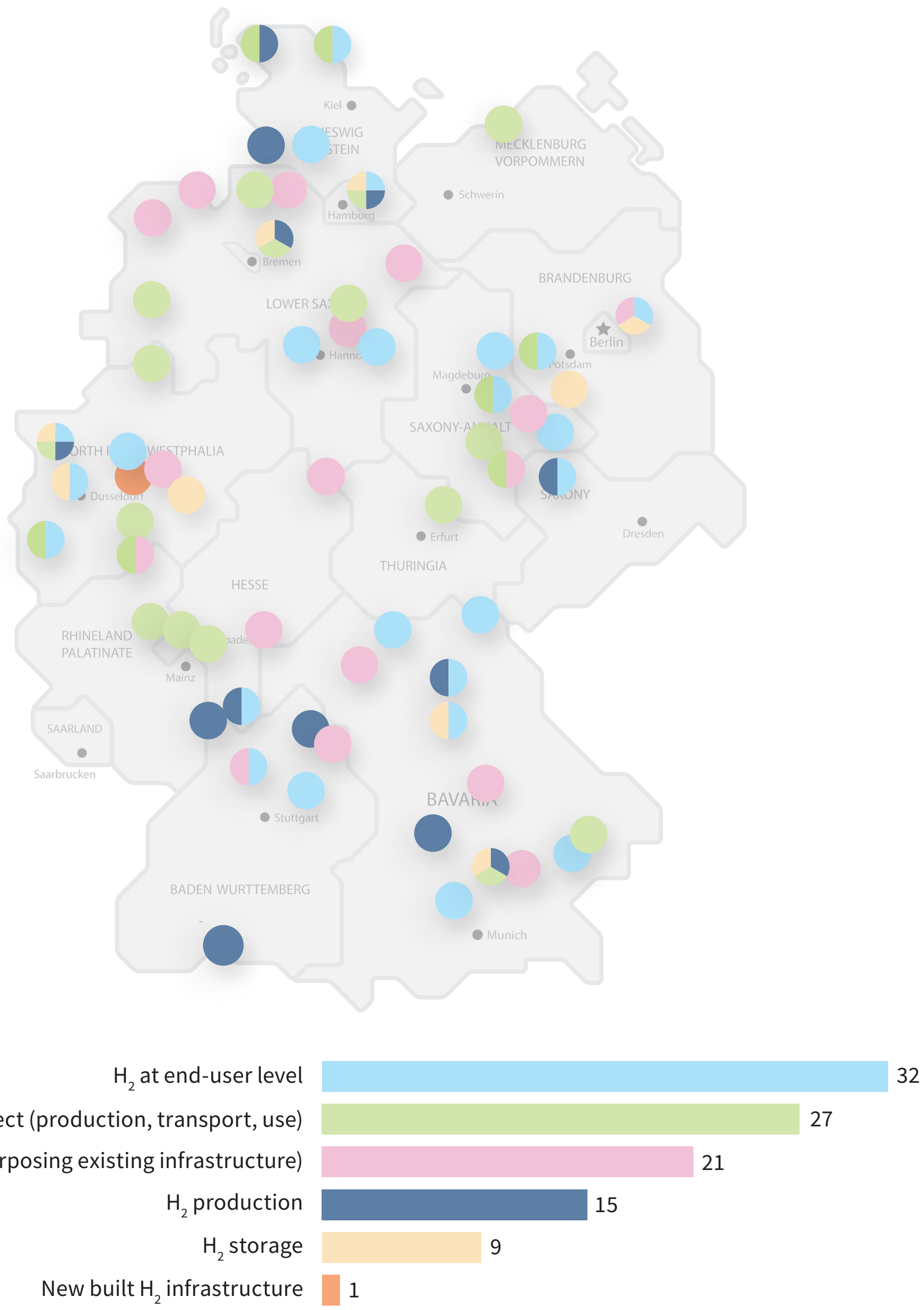


Figure 8: Hydrogen projects in Germany[34].

33 Agora Energiewende, AFRY, (2021). No-regret hydrogen: Charting early steps for H_2 infrastructure in Europe.
34 https://h2-project-visualisation-platform.entsog.eu/
35 DNV. Hydrogen Forecast to 2050. Energy Transition Outlook (2022).

Federal Minister for Economic Affairs and Climate Action Robert Habeck announced the decision to build a terminal for imports of green ammonia to Germany at the port of Hamburg. The terminal is to become operational in 2026. Green ammonia is going to be imported from Saudi Arabia, converted into pure hydrogen and distributed by Air Products to the final consumers.

Earlier this year, RWE announced its plans to build an ammonia terminal in Brunsbüttel to progress with the import of green molecules for the decarbonisation of industry. The planned commissioning date is 2026, the capacity is around 300 thousand tonnes of green ammonia per year. The next step is to build a facility to produce green hydrogen on-site.

Develop long-term storage systems for H_2

In the ramp-up phase of the hydrogen economy, it is considered that the role of hydrogen storage in securing reliable supply will be even more important than the current role of natural gas storage in the gas market. The need for underground storage at that horizon might exceed the repurposing potential of existing sites and new investments will need to come online.

Hydrogen storage can be categorized in the order of technology readiness level: storage tank; salt cavern storage; depleted oil & gas field, and aquifer (concept).

Integrate the regulatory system with policy coordination to reduce uncertainty

There is still work ahead to address the following issues: a regulatory framework for renewable hydrogen; incentivise demand; bankability of green hydrogen projects; a global certification system for hydrogen exchanges is needed (Guarantee of Origin; RFNBO Certificates); infrastructure (new and/or repurposed); priority for full-circle projects.

In order to define the requirements under which hydrogen or fuel produced from electricity (within or outside the EU) can qualify as renewable, the European Commission's published Delegated Act for the production of renewable liquid and gaseous transport fuels of non-biological origin ("Delegated Act on hydrogen production") as foreseen in art. 27 of RED II. Its draft (published in May 2022) contained strict requirements for hydrogen production based on three main principles: additionality, temporal and geographical correlations. The industry described the draft of the Delegated Act as the one which can "put brakes on green hydrogen"[36].

In September, the European Parliament voted to define its position regarding the production of renewable fuels of non-biological origin. The Parliament proposed easier requirements: there was no obligation that renewable generation capacity used to produce green hydrogen and other renewable fuels of non-biological origins should be new or additional; as for the temporal correlation, renewable power generation and hydrogen production will need to match on a quarterly basis until 31 December 2029. From 1 January 2030, the balance shall

36 New Delegated Act puts brakes on green hydrogen. RWE. May 2022

be achieved either on a monthly, quarterly, or yearly basis. This requirement shall apply to all existing plants, including the ones commissioned before 2030.

A new draft of the European Commission's Delegated act on hydrogen production is expected to be released on the 15th of December[37].

Design appropriate policy packages for production support

Suggested policies could include public support for investments, certification, Carbon Contracts for Difference (CCfDs), quotas for green hydrogen or hydrogen-based products, subsidies for green hydrogen production, electricity price and infrastructure regulation.

Green hydrogen is produced with the division of water into hydrogen and oxygen in an electrolyser that works on renewable electricity. Therefore, key factors that influence the price of green hydrogen are the cost of the electrolyser (CAPEX) and the cost of renewable electricity and water for the production process (OPEX) and the weighted average cost of capital (WACC).

As a supportive scheme for CAPEX costs, Germany has started the process of obtaining funding under the European initiative of IPCEI. Germany's Federal Ministry of Economics and Climate (BMWK) and the Federal Ministry of Transport (BMVI) selected 62 large-scale hydrogen projects that will be funded as part of an IPCEI Hydrogen project.

To incentivize the rollout of hydrogen projects important is to close the price gap between green hydrogen and hydrogen derived from fossil fuel. In 2021, Germany launched the H_2Global initiative, which aims to compensate for the difference between supply prices (production and transport) and demand prices with grant funding from the German government. Germany's Chancellor Olaf Scholz at COP27 announced 4-billion-euro funding in the framework of the H_2Global initiative, for supporting green hydrogen producers with long-term off-take agreements. The first tendering process for a long-term agreement with non-European countries will start soon. So, the country is building the foundation for importing hydrogen to expand the hydrogen economy in the future.

The EU supporting policy found serious competition in the face of the US with its Inflation Reduction Act, which includes many clean energy initiatives. Incentives for expanding wind and photovoltaics, ramp up of hydrogen, for example, 8 billion dollars to launch at least 4 hydrogen hubs across the US and tax credit of $3 per kilogram of hydrogen, produced with renewable and nuclear energy to stimulate clean hydrogen production. To be competitive, Canada proposed new tax credits up to 40 % for hydrogen investments.

37 LEAK: Long-awaited EU rules on renewable hydrogen expected 15 Dec. EURACTIV.com. December 2022

Develop strategic International Alliances.

It is important to evaluate how much Germany itself produces and invents what is needed for progress and how to compensate for the missing through cooperation with other countries. The German economy is heavily dependent both on the export of its products and on the import of energy and raw materials.

There are several dimensions of future mutual agreements for Germany:

1. with energy self-sufficient countries France, Norway, Canada, USA

2. cooperation with countries on gas, LNG (Norway, USA, UAE), Hydrogen (Canada, Australia, Norway, Netherlands, Northern Africa), and critical materials (China, Chile, Mexico, New Zealand, Australia, Ukraine, South Africa; Finland)

3. with countries with well-developed infrastructure (Spain and France on the new gas pipe from North Africa); Belgium, Netherlands on hydrogen transportation.

4. with innovation and technological leaders (in the EU - Finland, Denmark, the Netherlands, and Belgium, according to European innovation scoreboard 2022; Germany is a strong innovator)

The German delegation proposed an initiative to establish a "European Platform for Transformation Technologies" during the EU Competitiveness Council (Internal market and industry) in September 2022. The platform would help to strengthen the EU's technical sovereignty for the transformation. It would support the development of industrial value chains in key transformative technologies such as wind power, solar power, heat pumps and power grids as the supply of these technologies is currently well below demand, which has risen sharply as a result of the energy crisis.

The proposal evolved into the creation by the European Commission of a new platform, "Clean Tech Europe", to strengthen European value chains for clean energy and advance their global competitiveness. The kick-off of the platform was announced on the 30th of November, but the official document has not been released yet[38].

4.4 Mobility

The mobility sector is still dependent on mineral oil. Close to 92% of final energy consumption is based on liquid fossil fuels (gasoline and diesel). However, in 2021, almost 14% of the new passenger cars were battery-electric vehicles, which corresponds to almost 1 million cars in Europe[39].

38 EU determined to secure its clean energy industrial base. Wind Europe. November 2022.
39 Heymann E., German energy supply at a historical turning point. Deutsche Bank Research. March 2022.

- Rapid expansion of the private and public charging infrastructure. The EU Parliament members proposed to set mandatory national targets for the deployment of infrastructure; by 2026 there should be at least one electric charging station every 60 km along the main EU road and hydrogen refuelling station every 100 km.

- The European Commission granted 100 Mio. euros subsidies to the roll-out of new hydrogen refuelling stations in Germany, Netherlands, Belgium, Italy, Poland, Denmark, Sweden and France. Germany will receive 12.44 Mio. euros.

- Internal combustion engines phase out by 2035.

- Implementing EVs into the grid as remote batteries to balance electricity demand (vehicle-to-grid). Assuming that 25 % of electric cars will use vehicle-to-grid in 2035 and that an average of 40 per cent of these vehicles will be made available to the electricity market, the usable capacity will be 28 GW[40].

- Domestic production of automotive components for electrification.

Power-to-X processes are the game changers in the decarbonisation of hard-to-abate sectors (aviation, maritime, heavy-duty transport, public, and rail transport) and contribute to sector coupling.

The first step of the PtX process is the electrolysis of water, then, depending on the end-use application, H_2 is used to produce other energy carriers. PtX could produce synthetic fuels: e-Methane, e-Methanol, e-Diesel, and e-Kerosene, ready for instant use. They can be blended gradually with fossil fuels until they fully replace fossil fuels as a primary energy source. In this manner, the transition from a fossil world to a largely carbon-neutral environment can be done smoothly with immediate emission reductions on the way.

An example could be the international research project of Germany and South Africa CARE-o-SENE (Catalyst Research for Sustainable Kerosene). The announcement of this project was declared in May 2022 by South African President Cyril Ramaphosa and German Chancellor Olaf Scholz.

The CARE-o-SENE project funded by the German Federal Ministry of Education and Research (BMBF) and consortium partners, aims to contribute to ultimately reducing CO_2 emissions in the aviation sector by developing next-generation Fischer-Tropsch catalysts and optimising the production of sustainable kerosene on an industrial scale. Six partners from Germany and South Africa are involved in the CARE-O-SENE project.

40 Agora Energiewende, Prognos AG, Consentec GmbH (2022). Klimaneutrales Stromsystem 2035.

4.5 Flexibility and demand-side measures

Flexibility is utterly important for accommodating the increasing amount of renewable energy. In 2020, Germany paid more than 900 million euros in compensation for curtailed renewable energy production[41]. With increasing feed-in from fluctuating renewable energies and the decline in conventional power plant capacity, new flexibility options are needed to ensure a balance between supply and demand and allow more renewable electricity to be used directly. At the same time, it reduces the need to add gas-fired and coal-fired power plants and the necessary fuel input. Demand-side measures are key in tackling the current energy crisis.

Battery storage systems

Four basic types of energy storage (electrochemical, chemical, thermal, and mechanical) are currently available at various levels of technological readiness.

Hydrogen energy storage is a form of chemical energy storage in which electrical power is converted into hydrogen. H_2 could be consumed either as a fuel to produce power or as a feedstock or heat source for other industrial processes. H_2 is a promising solution for seasonal storage due to its low "self-discharge" property.

Battery storage systems is electrochemical storage systems, that have a fast response time and offer a wide range of possible applications in the stationary and mobile sectors. Due to their electrochemical properties, they have an efficiency of up to 99% and can be used by households, industry, energy suppliers, operators of photovoltaic and wind farms or providers of system services. The installed capacity of decentralised battery storage (in combination with rooftop PV systems) is 27 GW in 2030 and 51 GW in 2035 in Agora's scenario[39].

A quarter of the predicted European production capacities of battery cells could be covered by Germany. According to the research of the Fraunhofer Society, the production capacity in Europe is expected to reach 500 GWh by 2025 and 1.5 TWh by 2030. This could be as much as a quarter of the global capacity. The largest share of European production could be generated in the new production facilities in Germany – up to 400 GWh[42].

Electrolysers

Electrolysers, directly connected to the grid, can contribute significantly to grid flexibility. Electrolysers will be located near renewable power plants, in regions with abundant renewable energy generation (especially in the development stage) and can help to balance the system. In a period of high renewable generation, electrolysers can consume an excess of renewable

41 Bundesnetzagentur, Monitoring report 2021, from 15.03.2022.
42 Germany on the way to becoming a battery cell center. July 2022. Table.media

energy, and produce green hydrogen. So here electrolyser's work would help to avoid curtailment of RES electricity generation. This, in turn, will positively affect the price of producing green hydrogen – as electricity prices tend to be low during the period of high renewable generation.

Empowering consumers

The smart meter enables direct participation in the market of all consumers and the creation of new electricity products and services for consumers. Among them are net metering, data access, new innovative products, dynamic pricing models, and energy communities.

According to ACER's Annual Monitoring Report,[43] the share of household consumers with electricity smart meters at the end of 2021 in Germany is close to zero; the target of 80 % is set beyond 2024. The availability of smart meters is essential for enabling consumers' active participation in the market. The average penetration in the EU is 54 %. Leaders, that have reached 98 % are Denmark, Estonia, Spain, Finland, Italy, and Norway.

Vehicle-to-grid technologies reduce the need for small battery storage in homes and the need for large battery storage. It thus contributes to the efficient use of renewable electricity and resources.

Power-to-heat

A flexibility option for integrating electricity into heat applications: Power plants could be equipped with large thermal energy storage that can be charged by electricity from renewable sources and provide renewable energy as a "base load". Thermal storage power plants are a technologically available option for large storage in the range of several GWh already today. Innovative storage concepts for a temperature range from 100 to 1000 °C based on liquid and solid materials, latent heat storage and thermochemical systems are being developed by Institute of Engineering Thermodynamics at the German Aerospace Center (DLR). One of their research directions is a storage system, where molten salt will store energy from solar or wind farms in the form of heat and release it via turbines when needed.

43 Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2021. October 2022. ACER/CEER.

5. Climate Goals

The European Union is a frontrunner in terms of climate policy. The EU has decided to aim for achieving climate neutrality by 2050. Germany mirrored this goal and accelerated it by 2045. Germany's main milestones on this way include a reduction of 65 % in GHG emissions by 2030, 77 % by 2035, and 90 % by 2040.

Achieving climate neutrality requires achieving a balance between all greenhouse gas emissions (GHG) reduction across all sectors and the removal of GHGs from the atmosphere.

Carbon neutrality describes a state in which the CO_2 emissions are avoided, or compensated for these by reducing CO_2 emissions elsewhere, or by removing an equal amount of CO_2 from the atmosphere.

Decarbonisation refers to decreasing CO_2 emissions related to human activity processes. This is priority number one, as a tonne of CO_2 avoided will always be cheaper than a tonne of CO_2 removed from the atmosphere.

Globally, in 2019 total net anthropogenic GHG emissions came from electricity and heat (34 %), agriculture (24 %), and transportation (22 %)[44]. CO_2 accounts for about 75 % of total greenhouse gas emissions; methane, primarily from agriculture, contributes 18 % of greenhouse gas emissions and nitrous oxide, mostly from industry and agriculture, contributes 7 % to global emissions.

CO_2 as a resource. CCUS Carbon Capture, Utilisation and Storage: CCUS technologies are necessary on the path of reaching climate neutrality. For some industry branches, CCUS is the only option to decarbonise. The EU needs wide deployment of CCUS technologies to meet its Green Deal objectives (in the order they should appear) in the:

Power sector: Many existing power plants responsible for CO_2 emissions could operate for decades. These plants are needed to provide balancing power, as the level of renewable energy in the electricity mix increases.

Industry: CCUS is a solution for sectors with hard-to-abate emissions. In these sectors, alternatives to fossil fuels are either expensive (such as electricity to generate extreme heat), or even do not exist (for example, 2/3 of CO_2 emissions in the cement industry are process emissions).

44 IPCC Climate change 2022 report.

H_2 production: CCUS provides a cost-effective pathway for low-carbon hydrogen production.

Removing carbon from the atmosphere: There are several approaches to removing carbon from the atmosphere, including nature-based solutions (e.g., afforestation/reforestation) or technology-based carbon removal solutions – BECCS (biomass-fuelled power plants with CCS) and Direct Air Capture (DAC).

DAC could make a significant contribution to reducing greenhouse gas (GHG) emissions through two applications. First, by providing climate-neutral carbon dioxide for synthesis processes, DAC could function as an enabler for the production of electricity-based fuels (Power-to-Liquids (PtL)), gases (Power-to-Gas (PtG)), and chemicals (Power-to-Chemicals (PtC)). Second, DAC could act as a Negative Emission Technology (NET), by capturing large amounts of carbon dioxide from the atmosphere in combination with subsequent long-term geological storage (Direct Air Carbon Capture and Storage (DACCS)).

Captured CO_2 can be used combined with hydrogen to produce synthetic fuels, as a feedstock to produce cement or plastics, in food processing, in the building industry or even to produce diamonds.

The cost of DAC today is very high due to the large amounts of energy needed, both to power fans inside the collectors and to heat the filters to release captured CO_2. The two leading DAC technologies – solid DAC (S-DAC) and liquid DAC (L-DAC) – were initially designed to operate using both heat and electricity.

Currently, 18 direct air capture facilities are operating in Canada, Europe (e.g., Iceland), and the United States, capturing 0.01 Mt CO_2/ year. The new project in the USA, developed by Occidental company, aims to remove 1 million tonnes of CO_2/year – 100 times bigger than all currently operating DAC plants[45].

The global capacity for carbon capture in 2030 is set to increase sixfold from today's level to 279 million tons of CO_2 captured per year, if all announced projects will be developed, according to BloombergNEF[46].

The European Commission has been supporting DAC through various research and innovation programmes (including the Horizon Europe programme and the Innovation Fund, launched in 2020 for the decade 2020–2030 with an initial budget of around USD 11.8 billion) and more broadly

45 Occidental plans up to $1 bln for facility to capture carbon from air. Reuters. March 2022.
46 Global Carbon Capture Capacity Due to Rise Sixfold by 2030. BNEF, October 18, 2022

carbon dioxide removal through its first Communication on Sustainable Carbon Cycles[47], which suggests that 5 Mt of CO_2 should be removed annually by 2030 from the atmosphere through the land- and technology-based approaches such as DAC.

To elevate further development of CCUS projects the European Commission adopted a proposal for the first EU voluntary certifying framework for carbon removals[48]. It is needed to enable to quantify, monitor and verify carbon removals capacity.

Certification methodology for the different types of carbon removal activities will be based on the four **QU.A.L.ITY** criteria:

1. **Quantification:** Carbon removal activities need to be measured accurately and deliver unambiguous benefits for the climate;

2. **Additionality:** Carbon removal activities need to go beyond existing practices and what is required by law;

3. **Long-term storage:** Certificates are linked to the duration of carbon storage so as to ensurepermanent storage;

4. **Sustainability**: Carbon removal activities must preserve or contribute to sustainability objectives such as climate change adaptation, circular economy, water and marine resources, and biodiversity.

Further development on that matter is planned for the first quarter of 2023.

↘ Figure 9 shows the current CCU projects in Germany based on the data of the CO_2 Value Europe (CVE), the non-profit association representing the Carbon Capture and Utilisation (CCU) community in Europe since 2017.[49]

47 The European Commission Communication on Sustainable Carbon Cycle, December 15, 2021

48 European Green Deal: Commission proposes certification of carbon removals to help reach net zero emissions. Press release. November 2022.

49 CO_2 Value Europe website co2value.eu

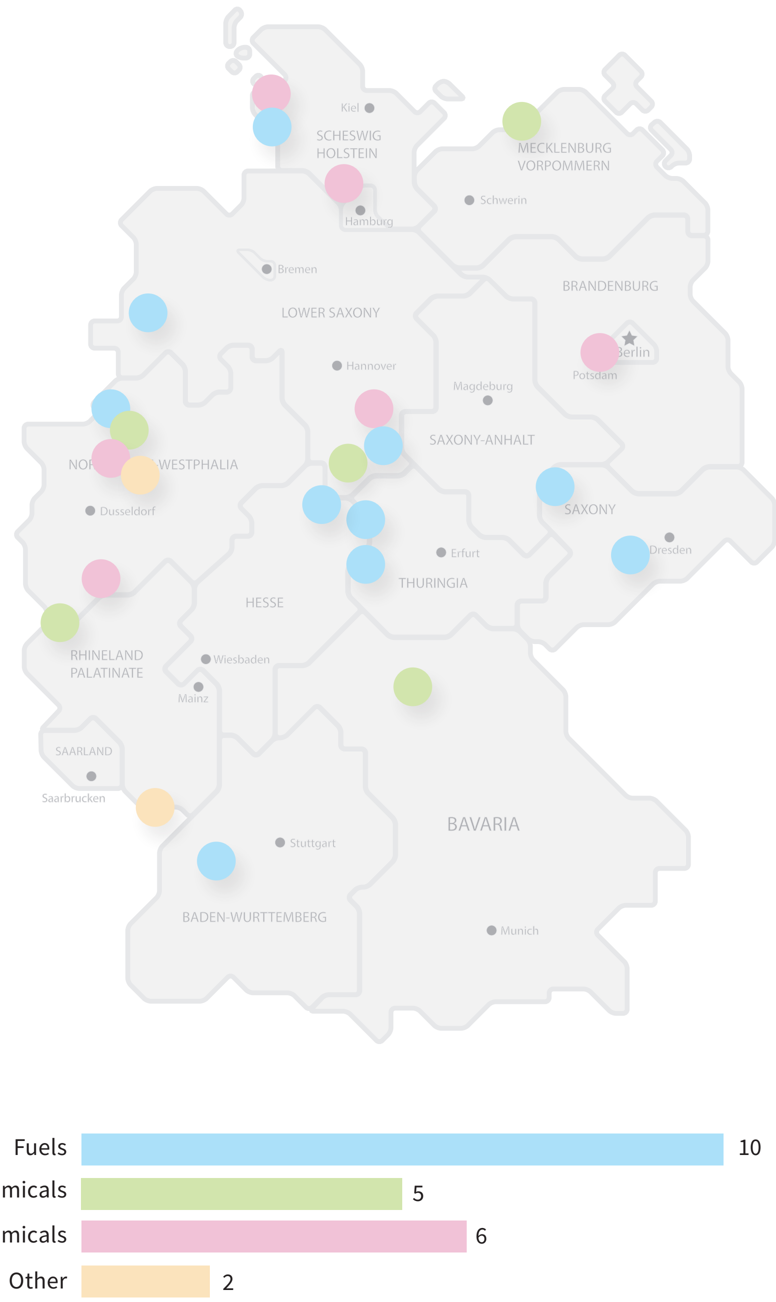


Figure 9: CCUS projects in Germany[49].

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