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Update 2024: Greenhouse gas savings and the associated hydrogen demand in Germany

1 BACKGROUND AND CLASSIFICATION

The German National Hydrogen Council (NWR) published an initial demand analysis in the NWR whitepaper 'Greenhouse gas savings and the associated hydrogen demand in Germany' from 1 February 2023[1], which provided estimates of hydrogen demand in Germany for key sectors. The hydrogen demands of the steel production, chemical, mobility and – with limitations – heating industry were determined for the NWR whitepaper based on the respective industry's strategy for achieving the climate targets. The geopolitical upheavals following Russia's attack on Ukraine and the resulting changes, especially for the energy sector, were already considered at that time, but the NWR was nevertheless aware that a more in-depth analysis of individual sectors was necessary, but that it would also take time. Since then, the uncertainties and imponderables have tended to increase: the challenging geopolitical situation in Europe has been exacerbated by the conflict in the Middle East, while geoeconomic competition for value creation has not diminished. Project financing has not become any easier due to inflation and cost pressure as well as the national and EU legal and regulatory framework, which is hampering the development and ramp-up of hydrogen at all stages of the value chain and in the various sectors. Despite these uncertainties, the NWR is keen to provide as realistic an estimate as possible of expected demand levels in the expectation that the political and legal framework will be adequately organised in the coming years and that the market ramp-up can reach a corresponding level.

The previous needs were updated by industry representatives in the 'Update 2024: Greenhouse gas savings and the associated hydrogen demand in Germany' on the basis of an assessment of realistic projects and plans and taking into account relevant regulatory requirements. The needs from the process industries of non-ferrous metals, non-metallic minerals, glass and paper manufacturing, mechanical engineering and plant construction were also included. Further, there is also an assessment of the needs of the electricity sector. Demand for 2030 is now estimated at approx. 94–125 TWh. The minimum demand of 94 TWh for 2030 is therefore 68 per cent higher than the predicted demand from February 2023, which calculated a minimum demand of 56 TWh, although this demand also includes a certain amount of grey hydrogen (see Section 2.1 – Chemical industry).

[1] NWR white paper: 'Greenhouse gas savings and the associated hydrogen demand in Germany' from 1 February 2023.

The demand for 2030 corresponds to an electrolysis capacity of 39–52 GW[2], without it being possible to say whether this would have to be installed domestically or abroad: the question of the origin of climate-neutral or virtually climate-neutral hydrogen is also not further examined in this update. In addition, the quantity structures presented here for the future demand for hydrogen and hydrogen derivatives are based on the assumption that there will be no large-scale relocation of hydrogen-relevant industries abroad in view of the resilience of the German economy and any carbon leakage effects.

2 DEMANDS IN DIFFERENT SECTORS

The key interest of all stakeholders as regards an assessment of hydrogen demands does not only lie in the year 2030, as a relevant market for green hydrogen and derivatives should be created by 2030; however, the ramp-up will mainly gain momentum in the 2030s. In this regard, the years 2035 and 2040 are also considered before the demand required for complete climate neutrality in 2045 is specified.

2.1 PROCESS INDUSTRIES

For various industrial sectors, natural gas is not only a source of energy, it is also a necessary part of production as a process gas. Electrification is mostly impossible in the process industries, or at least uneconomical. This is why making a switch to using hydrogen or synthetic natural gas (SNG) as a process gas is usually the only way towards achieving carbon-neutral production.

Steel industry

For the steel industry, climate-neutral hydrogen is indispensable for running production in a way that is climate-neutral. The hydrogen is for the most part needed as a reducing agent for the direct reduction of iron ore for primary steel production and serves as an energy source in various high-temperature processes in secondary steel production and downstream steel processing. CO_2 emissions reductions with a particularly high efficiency factor can be realised (28 t CO_2 per 1 t H_2 by replacing coal), especially when used in the direct reduction plant.

The steel industry will need several hundred thousand metric tons of hydrogen per year from as early as 2026, most of which will have to be supplied via pipeline connections. This is associated with considerable CO_2 reduction potential, provided that connections to the hydrogen core network are made in good time. The plants can also be operated flexibly with natural gas until climate-neutral hydrogen is available in sufficient quantities at economic prices, thus saving 60 per cent of today's CO_2 emissions already. Blue hydrogen will play an important role in the ramp-up phase.

The hydrogen requirements of the steel industry have become much more concrete compared to the last needs analysis by the NWR[3]. The investment plans for the switch to climate-neutral production have been pushed ahead intensively and the steel industry is in the middle of the first transformation stage. The IPCEI (Important Projects of Common European Interest) projects have now been approved or funding decisions have (for the most part) been handed over. The predicted demand for 2030 has increased significantly once again. For 2030, it is expected that around 14–15 million metric tons of pig iron capacity (this corresponds to around half of the existing capacity) will be replaced by direct reduction plants. However, this is based on the assumption that the outstanding investment projects will be

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[2] Based on the lower calorific value (Hu) of H_2, at 60 per cent efficiency and 4,000 full load hours p.a.

[3] See the NWR white paper: 'Greenhouse gas savings and the associated hydrogen demand in Germany' from 1 February 2023.

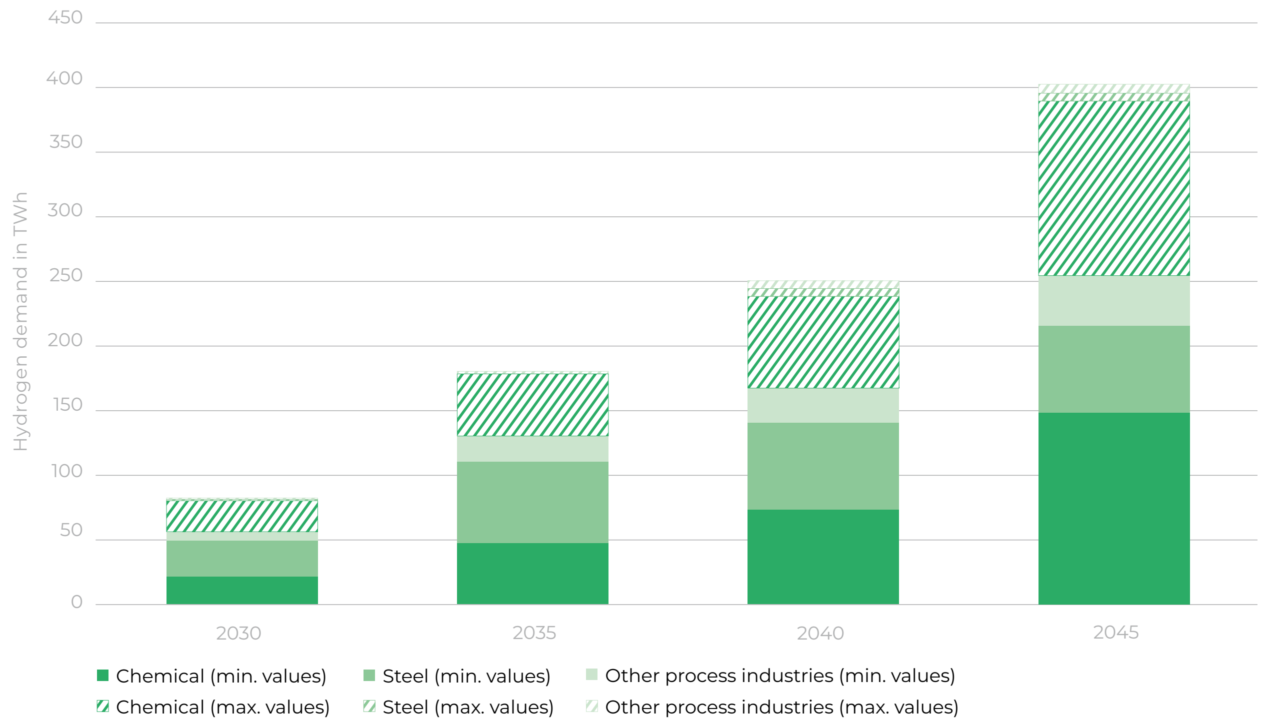
included in the upcoming tender rounds for climate protection contracts after the projects that have already been subsidised.

This results in a demand of between 28 and 29 TWh for 2030, provided the plants are operated entirely with climate-neutral hydrogen, whereby smaller quantities (around 0.4 TWh) could be used in further processing. This is associated with a CO_2 reduction potential of around 23 million metric tons through the use of climate-neutral hydrogen in direct reduction alone.

The demand for hydrogen in the steel industry after 2030 will continue to increase significantly, as conventionally produced steel will lose competitiveness at an accelerated rate due to rising CO_2 prices, the expiry of the free allocation of emission allowances and the end of the issue of emission allowances in the EU ETS in 2038. 1.8 million metric tons (60 TWh) of hydrogen would be required to operate the direct reduction plants if all primary capacities were fully converted by 2035. By 2030 and by 2045, there will be a further 0.1 million metric tons (3.3 TWh) and 0.4 million metric tons (13.4 TWh), respectively, of green hydrogen required for further processing and various high-temperature processes in electrical steel plants.

These estimates regarding quantities are based on the assumption of a constant recycling rate for steel and a complete replacement of coal in blast furnaces with hydrogen as a reducing agent for primary steel. The hydrogen demand for steel will be lower if increased utilisation of steel scrap in electric arc furnaces for the production of secondary steel is assumed. However, the options for substituting primary steel with steel scrap are limited by the limited global availability of steel scrap and customer-specific quality requirements. It is not expected that scrap volumes in Germany will increase by more than 10 per cent by 2045, which would lead to a minimum demand of 2.0 million metric tons (67 TWh) if production remains the same.

Figure 1: Hydrogen demands in the chemical, steel and other process industries



Chemical industry

The goal in the chemical industry (excluding refineries) is to replace the existing hydrogen demand of approx. 1.1 million metric tons (37 TWh) (grey hydrogen up to now) with climate-neutral hydrogen.[4] Doing this requires completely new plant concepts that have to be invested in, especially in the case of ammonia production. These investments are most likely not to be expected until the 2030s due to reasons of economic efficiency. The impact that the expected massive import of green ammonia as the main hydrogen carrier for transport will have on national ammonia production should also be noted, as it makes it difficult to forecast quantities.

The considerable, **additional** hydrogen demand in the future results from the necessity to also make the raw material basis, which has been comprised of mostly fossil resources to date, greenhouse gas-neutral. The use of CO_2 as a source of carbon will play a role here in addition to increased recycling efforts and the use of biomass. Hydrogen is needed as the most important co-factor for the conversion of CO_2 into greenhouse gas-neutral hydrocarbons as a raw material (green naphtha) or directly as basic chemicals (methanol).

The development of future requirements depends largely on which technology paths are pursued in the course of the transformation of the chemical-pharmaceutical industry and which growth assumptions are made. The Chemistry4Climate stakeholder platform analysed three scenarios in its final report[5]: assuming maximum use of electricity-based technologies, hydrogen demand will be 22 TWh in 2030, 90 TWh in 2040 and 214 TWh by 2045, where these quantities are only used in material form. If hydrogen-based technologies are prioritised, demand will already be 45 TWh in 2030, 144 TWh in 2040 and 283 TWh in 2045, which corresponds to an eightfold increase compared to the consumption now. If technologies from the circular economy and biomass are prioritised, demand will reach 21 TWh in 2030, 73 TWh in 2040 and 148 TWh in 2045. In the second and third scenarios, 9 TWh (2030), 21 TWh (2040) and 42 TWh (2045) of the aforementioned quantities are expected to be used for energy. As these are ideal scenarios, actual demand is likely to be within the ranges mentioned. Derivatives (ammonia and methanol, for example) account for a proportion of the ranges shown here, as the growing demand for hydrogen in the chemical industry is likely to require the additional import of climate-neutral or largely climate-neutral hydrogen and hydrogen derivatives in addition to domestic production. The framework conditions for imports are to be set out in the hydrogen import strategy announced by the German government.[6] A quantitative distinction between hydrogen and derivatives is not possible at the present time as an estimate from real projects or derivation from industry scenarios. However, in the Kopernikus scenarios P2X[7], the hydrogen demand for downstream products was broken down in detail. For example, in 2045, there will be a hydrogen demand of 17 TWh for ammonia, 9 TWh for methanol, 114TWh for high value chemicals in the steam crackers and an additional demand of 115 TWh for the derivative FT crude. In addition, there is an SNG demand of 12 TWh for non-electrifiable industrial process heat above 500°C for carbon black (4 TWh) and soda (5 TWh), among others. In 2030, there will be a hydrogen demand of 5 TWh for ammonia, 5 TWh for methanol and 13 TWh for high value chemicals, as well as an SNG demand of 1 TWh for industrial process heat above 500°C.

[4] For 2030, it is assumed that the demand of the chemical industry, which has been covered by grey H_2 up until now, will only proportionally be covered by climate-neutral or mostly climate-neutral hydrogen. This means that the data for 2030 also concerns the demand for grey hydrogen. The hydrogen demand identified will be gradually converted to exclusively climate-neutral hydrogen by 2045.

[5] Chemistry4Climate (2023): Final report.

[6] See also the NWR publication entitled 'Statement on the development of the German government's hydrogen import strategy' from 19 January 2024.

[7] Kopernikus project 'P2X: Erforschung, Validierung und Implementierung von "Power-to-X"-Konzepten [P2X: Research, validation and implementation of Power-to-X concepts]'.

Other process industries

The fundamental question of the extent to which gas can be replaced by carbon-neutral substitutes, such as hydrogen, and with which timescales, arises not only for the steel and chemical industries, but also for a number of other industrial sectors in Germany, such as **glass and paper production**.

In these two industries, the natural gas used in energy-intensive processes can be replaced by hydrogen and, in the paper industry, by biomass due to lower temperature levels, thus gradually reducing the share of CO_2 emissions. Hydrogen is also of crucial importance for the decarbonisation of the glass industry, as the complete electrification of the glass production process is very complex and in turn expensive for technical reasons. Bundesverband Glasindustrie e.V. (Federal Association of the German Glass Industry) expects hydrogen demand to reach around 1 TWh by 2030. On the other hand, the paper industry anticipates a demand of around 5 TWh in 2030. The glass industry's demand will rise only slowly to around 2 TWh in the second stage of the ramp-up to 2035. On the other hand, the paper industry is already anticipating a demand of 17 TWh of hydrogen, as its gas-based CHP power plants are expected to be converted to hydrogen for the most part by then. Trials have already been conducted with hydrogen-ready gas-fired turbines. These cannot only generate heat and steam for their own production, but also contribute to regional grid stabilisation when the supply of wind and PV power is low. As a result, they already play a dual role as energy-intensive consumers and feeders of electricity into the grid. Several hydrogen projects have also been carried out in the glass industry. In addition to projects in semi-industrial plants, such as HyGlass and H_2Glass, the large-scale application in a glass melting tank should be mentioned here.

There is also a material and energy demand for hydrogen in the **non-ferrous metals industry**. Hydrogen – similar to primary steel – is required as a reducing agent for climate-neutral lead and zinc. This results in a hydrogen demand of 0.4 to 0.6 TWh in 2030, of which 0.4 TWh alone is reserved for material uses, and of 4.7 to 5.3 TWh in 2045.[8]

The **non-metallic minerals industry** will also require hydrogen and SNG, which the sector estimates at around 1 TWh in 2030 and around 8 TWh in 2045.[9] The large furnaces for the production of bricks, lime and cement, for example, still operate using fossil fuels in many cases. However, secondary fuels are already being used on a large scale in cement plants, for example, which enable considerable CO_2 savings compared to coal. The industry is endeavouring to gradually reduce the use of fossil fuels. In addition to the use of hydrogen, biomass utilisation, electrification and other efficiency improvements will also play a role on the road to decarbonisation.[10]

Around 1–2 TWh of gas is currently used in production processes in **mechanical engineering and plant construction** for processes such as heat treatment, hardening, drying etc. and would have to be converted to hydrogen (or, if technically possible, electricity) in future (that is, in the 2030s) according to estimates by the German Mechanical Engineering Industry Association (VDMA). Heating in buildings is not included, even if there may be some interactions in individual cases, for example, through combined heat and power generation.

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[8] See footnote 7.

[9] See the following publications for more information: Bundesverband der Deutschen Ziegelindustrie e.V. (2021): 'Roadmap für eine treibhausgasneutrale Ziegelindustrie in Deutschland [Roadmap for a greenhouse gas neutral brick and roof tile industry in Germany]'; Bundesverband der deutschen Kalkindustrie e.V. (2020): 'Roadmap Kalkindustrie 2050 [Roadmap for the lime industry by 2050]'; Verein Deutscher Zementwerke e.V. (2020): 'Dekarbonisierung von Zement und Beton – Minderungspfade und Handlungsstrategien [Decarbonisation of cement and concrete – measures to reduce emissions and strategies for action]'.

[10] Greater demand was estimated in the Kopernikus project P2X: Erforschung, Validierung und Implementierung von 'Power-to-X'-Konzepten [P2X: Research, validation and implementation of Power-to-X concepts] (1.4 TWh in 2030, 12–13 TWh in 2045); however, this does not appear to take into account the potential for reduction through current efforts in the sector.

2.2 TRANSPORT SECTOR

Hydrogen produced in a climate-friendly way can present a significant contribution to achieving goals in the transport sector, too. In addition to directly used renewable electricity, hydrogen and hydrogen-based fuels will already become the most important energy source in the medium term, especially in road-based heavy goods transport, shipping, aviation and rail transport. The use of hydrogen or hydrogen-based fuels is an important solution wherever many people or heavy goods are transported over long distances. Germany's security institutions also need a robust energy supply and must address this at an early stage as part of the transformation, with the same applying to the construction industry and agriculture. The use of hydrogen and hydrogen derivatives in the mobility sector was examined in the following in relation to applications, both for road-based transport and for other applications.

Private transport including light commercial vehicles

These days, the passenger car transport sector focuses mainly on battery-electric powertrains to meet its CO_2 emission reduction targets. As long as the expansion of the necessary charging infrastructure, including the associated electricity grids, is successful and the necessary critical raw materials for the battery are made available, a substantial market share should be achieved. Some manufacturers, some of which are focused on areas outside the EU, are also working on further developing fuel cell electric vehicles as a supplementary market segment. It should be stressed that these developments are mostly taking place outside of Germany within different political and geographical frameworks and that economically competitive alternatives to battery electric passenger cars can be expected to come from there. The expected hydrogen demand for passenger car applications is relatively low at less than 1 TWh, at least for 2030; however, the demand for light commercial vehicles is already greater. A European manufacturer announced the sale of fuel cell vans, shored up by support measures from the French government, in 2023. The NWR assumes that hydrogen demand for light commercial vehicles will grow to just under 1 TWh by 2030. By 2040, hydrogen demand is expected to grow to around 8 TWh due to its utilisation characteristics (long range and higher load capacity). By this time, the light commercial vehicle segments should be largely decarbonised while having achieved the corresponding economic efficiency.

Heavy-duty commercial vehicles including buses

It is likely that the European Union will decide to tighten the CO_2 emission reduction targets for heavy-duty commercial vehicles in May 2024. For the first time, city buses and coaches will also be regulated in their CO_2 emissions, and not only lorries with a gross vehicle weight of more than 3.5 metric tons.

Some lorry manufacturers have announced or already launched fuel cell vehicles for longer ranges, alongside battery-electric lorries, in order to achieve the EU targets. The predicted quantity of just under 0.5 million metric tons of H_2 (17 TWh) for 2030[11] mentioned in NWR's 2023 whitepaper was based on the assumption that, in addition to H_2 utilisation in refineries, approx. 38,000 heavy-duty vehicles (HDVs) with fuel cells will be licensed in Germany.[12]

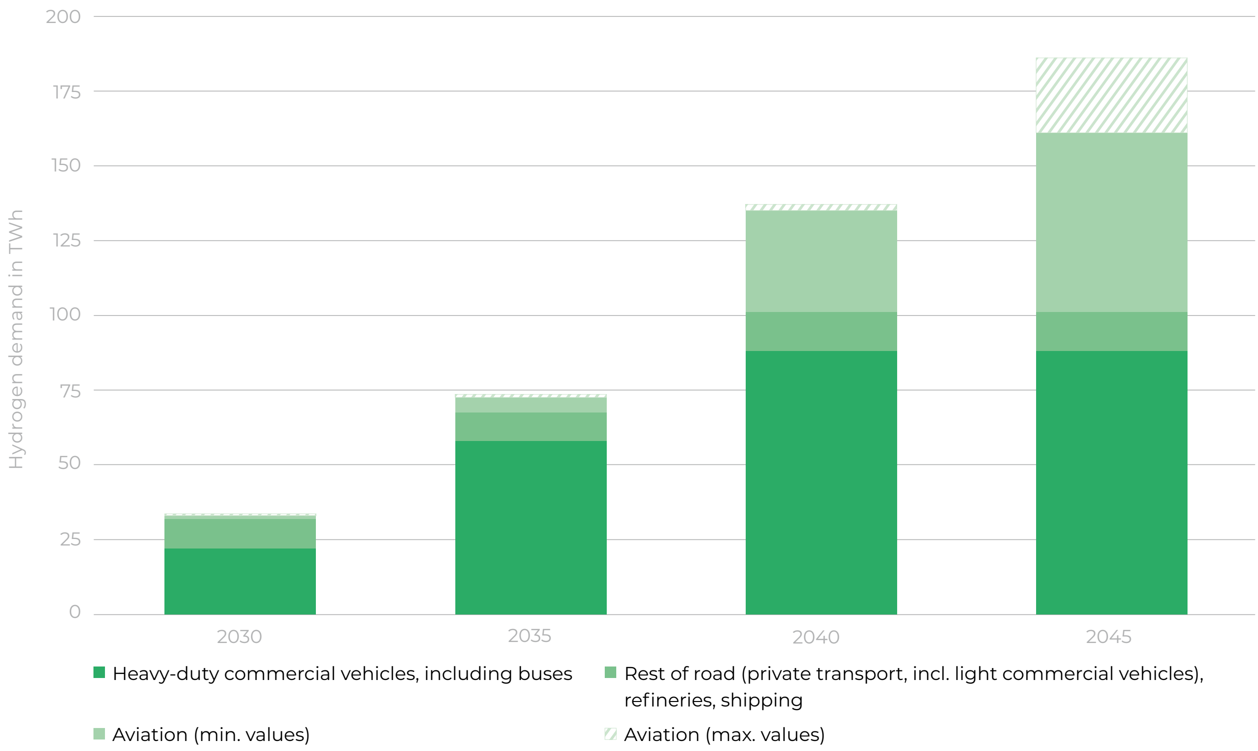
[11] NWR white paper: 'Greenhouse gas savings and the associated hydrogen demand in Germany' from 1 February 2023.

[12] A study commissioned by the German Federal Ministry of Transport in 2023 showed that by 2030, about 38,000 H_2-powered lorries will be licensed. An annual consumption of approx. 380,000 t H_2 can be expected for these HDVs. On top of that, there are another approx. 100,000 t H_2 for lorries that are licensed outside of Germany but will be travelling in Germany and therefore have to be refuelled there (NOW (2023): 'Marktentwicklung klimafreundlicher Technologien im schweren Straßengüterverkehr [Market development of climate-friendly technologies in road freight transport of heavy goods]').

Based on the increased CO_2 emission reduction targets, the NWR now expects that around 50,000 lorries and around 5,000 hydrogen buses will be in use in 2030, resulting in a hydrogen demand of around 22 TWh. The target for 2035 for heavy-duty commercial vehicles of reducing CO_2 emissions by 65 per cent compared to 2019 will further increase the consumption of hydrogen. On the one hand, the number of vehicles is increasing due to new registrations, while on the other hand new segments will be occupied due to falling hydrogen costs, so that a total hydrogen demand of approx. 58 TWh is expected for 2035.

The regulation for heavy-duty commercial vehicles stipulates that 90 per cent of CO_2 emissions must be reduced by 2040 compared to 2019. In addition to around 500,000 battery-powered lorries and buses, around 300,000 hydrogen lorries would then be licensed and operated in Germany. The hydrogen demand of these vehicles amounts to around 88 TWh.

Figure 2: Development of hydrogen demand in the transport sector (excluding e-fuels beyond aviation and shipping)



Refineries

For methodological reasons, here, the use of hydrogen in refineries is attributed to the mobility sector. It is assumed that the hydrogen currently being used in this sector, which is produced from natural gas – also driven by the requirements of RED II – can be replaced by green hydrogen relatively quickly. Overall, it is currently calculated that there is a net demand for hydrogen of around 5.7 TWh to desulphurise fuels, which is currently produced by natural gas reformation. This potential is likely to be tapped quickly due to the high level of self-interest among refinery operators, so that consumption of around 1.7 TWh of green H_2 is already expected in 2030[13]. A rapid substitution of grey hydrogen by green hydrogen is to be expected due to pressure from high penalties, so that the consumption of green hydrogen will increase to around 4 TWh by 2035. However, the picture is likely to change towards the end of the coming decade: refineries will also have to desulphurise less fuel as the consumption of fossil fuels by transport decreases, so the NWR expects the consumption of green hydrogen to slow to around 2 TWh by 2040.

Aviation

Feasibility studies and economic analyses show that hydrogen can be a decisive component of future aviation technology. The ReFuelEU Aviation regulation and the quotas for the proportion of sustainable aviation fuels (SAF) and the sub-quota for electricity-based fuels are key regulatory framework conditions (particularly on the part of the EU). In addition, licensing and certification aspects are also relevant in the production of sustainable and climate-friendly fuels in aviation.

The expected demand for hydrogen, regardless of the form of utilisation (direct combustion or use of hydrogen in other processes, such as Fischer-Tropsch), is 1.4 to 1.6 TWh in 2030 and 60 to 80 TWh in 2045.

Shipping

Hydrogen and its derivatives play a crucial role in decarbonisation for the maritime sector, as direct electrification in this sector will only succeed in very specific areas at best. Nevertheless, the quantities to be considered for Germany in 2030 are to be estimated as rather low (approx. 21,000 t H_2, which corresponds to about 0.7 TWh). The quotas introduced by the EU of 1 per cent in 2031 and 2 per cent in 2034 (if the 1 per cent quota is not reached in 2031) lead to a demand of around 0.8 and 1.5 TWh H_2, respectively. However, an estimate is difficult due to the complex regulatory framework (with various interactions) and the fact that the market has hardly existed to date. The Kopernikus scenarios envisage a demand of 3 TWh for 2040 and 5 TWh for 2045.[14]

The role of e-fuels

In 2030, 75 per cent of all existing vehicles on the road are expected to still be equipped with an internal combustion engine as the ramp-up of electromobility has been slow since the end of the subsidy programme. In this regard, a market ramp-up of virtually climate-neutral, hydrogen-based fuels, which is necessary for aviation and shipping, can bring about further greenhouse gas reductions in the transition phase. For all applications that are difficult to electrify, where neither vehicles nor infrastructure for direct hydrogen use are available, or where avoiding transport and shifting modes of transport are not possible, electricity-based fuels could also be used; for example, for vehicles in the construction industry, agriculture and Germany's security institutions. A conservative estimate by the NWR estimates just under 6 TWh in 2030, which would likely be imported from countries outside the EU as hydrogen-based

[13] As of today, around 450,000 metric tons of H_2 are produced or used in refineries in Germany, but only 170,000 metric tons of this is from the externally supplied natural gas for desulphurisation. Internal refinery processes are not taken into account here, as replacing this process-related hydrogen would not contribute to a CO_2 emission reduction.

[14] See footnote 7.

derivatives containing carbon (for cost reasons). It remains unclear from today's perspective whether the latest European requirements (RED III) could lead to higher demand here; for this reason, among others, the assessment from NWR's 2023 whitepaper[15] has not been changed here. The question of the extent to which the import of e-fuels is possible from a regulatory perspective is also not addressed here.

Other applications

The use of fossil diesel in rail transport is being restricted more and more. Hydrogen and fuel cells are significant alternatives here, though they will foreseeably only lead to manageable hydrogen demand quantities and must be anchored in the European developments accordingly, especially against the backdrop of the new trans-European networks.

2.3 HEATING MARKET

The heating sector is responsible for more than half of Germany's energy demand and is an important segment for achieving climate protection goals. The bottom-up study on the heating market[16] commissioned by the NWR has shown that a 'one-size-fits-all' solution does not exist, but rather a bundle of technological options is necessary for decarbonisation. Heat pumps, heating grids, heat from renewable sources and hydrogen play the most important roll. Hydrogen is particularly indispensable for district heating and process heat and is up to 40 per cent cost-effective, regardless of the cost development considered. But hydrogen can also play a role in the decentralised space heating sector, especially in areas where district heating is less prevalent. The heating market varies greatly from one place to another, and a reliable sales forecast is only possible once the locally suitable decarbonisation strategy has been identified in all of Germany's supply areas in the course of municipal heating planning efforts. However, the analyses have shown that in all supply areas, the decarbonisation strategies up to 2030 are essentially the same and the use of hydrogen in the heat market will only take place thereafter.

An initial projection based on the four supply areas analysed for the bottom-up study shows (depending on the scenario) a hydrogen demand for centralised and decentralised heat generation totalling 5–10 TWh in 2030 and then a rapid increase in demand to a magnitude of 125–500 TWh in 2045. The topics of process heat and combined heat and power (CHP) are included in this section insofar as consumers are connected to distribution grids. Other quantities are not found here but can be found in Section 3.1 Process Industries.

2.4 ENERGY SUPPLY

The use of hydrogen in the energy sector for the production of electrical energy played only a minor role in the NWR's previous analyses for 2030. At the same time, with the completed phase-out of nuclear power and the advancing phase-out of coal, necessary investments in secured power plant capacity up to 2030 and beyond are pending. The German government has presented key points for the power plant strategy in order to ensure that these capacities can also guarantee security of supply in a completely climate-neutral energy system by 2045. Up to four times 2.5 GW of H_2 power plant capacities are to be put out to tender, which are to be completely converted to hydrogen between 2035 and 2040. What's more, there will be subsidies for up to 0.5 GW of pure hydrogen power plants. In addition, concepts for a market-based, technology-neutral capacity mechanism are to be developed, which should be operational by 2028 at the latest. There is another relevant factor influencing the speed of the hydrogen ramp-up in electricity generation with the last allocation of emission allowances in 2038.

[15] NWR white paper: 'Greenhouse gas savings and the associated hydrogen demand in Germany' from 1 February 2023.
[16] NWR study: 'Bottom-up study on possible pathways for an efficient and socially responsible approach to decarbonisation of the heating sector' from 8 December 2022.

As flexible and climate-friendly systems for generating electricity, hydrogen power plants and their storage systems ensure security of supply even at times when there is little sun and wind. However, this results in lower full load hours. The development of electricity demand, storage and other flexibility options, installed power plant capacities of 40 to 70 GW will be required in 2045 depending on the expansion of renewable energies. The NWR expects a hydrogen demand of up to 30 TWh for 2035 and 200 TWh for 2045 for the period under consideration. In 2045, the use of 80 to 100 TWh of hydrogen is considered necessary system-relevant in order to ensure a stable power supply in winter, including new consumers such as electric vehicles and heat pumps, and to keep the critical infrastructure operational. Additional volumes will largely be characterised by the price development of climate-neutral hydrogen.

It should be noted that the demands regarding electricity generation partly overlap with the CHP segment of centralised heat generation.

3 SUMMARY AND PROGNOSIS

The earlier demand analysis from 2023 ('Greenhouse gas savings and the associated hydrogen demand in Germany') had already presented the previously determined demand for green hydrogen in Germany. According to it, hydrogen will play a significant role in reducing greenhouse gas emissions in industry, especially the steel and chemical industries, as well as in the mobility, heating and energy supply sectors. The currently estimated use of hydrogen harbours enormous CO_2 savings potential; around 50–55 million metric tons of CO_2 per year can be avoided by 2045 in the steel industry alone. As outlined in the needs analysis from 2023[17], the CO_2 avoidance lever is particularly pronounced in the steel industry with 25 metric tons of CO_2 avoided per metric ton of green hydrogen used, as a direct switch from coal to hydrogen as a reducing agent is possible here thanks to the technological shift to the hydrogen-based DRI reduction process.[18]

The hydrogen demands of all sectors in Germany for the years 2030, 2035, 2040 and 2045 (that is, the year in which Germany wants to become climate neutral) are based on data from the respective industrial sectors, as presented (see Table 1). This information was checked for plausibility and therefore provides a rough yet valid overview of expected quantities that have to be produced in or imported to Germany. This is naturally associated with great uncertainty for 2045. This is also due to the fact that it is not yet foreseeable to what extent the potential of efficiency gains and alternative energy sources/raw materials can be realised technically and economically, which would reduce the demand for hydrogen in the individual sectors. These include:

- in the steel industry, for example, the expansion of the circular economy to include an increased proportion of electrical steel,
- in the chemical industry, for example, the extension of product lifetimes, reduction of single-use plastics, etc. with an overall savings potential of 15 to 24 per cent,[19]
- in the paper industry, for example, the use of sustainable biomass for process heat or industrial heat pumps at temperatures <200°C,

[17] See Figure 4 in NWR's white paper: 'Greenhouse gas savings and the associated hydrogen demand in Germany' from 1 February 2023.
[18] This results in an efficiency factor of 28 metric tons of CO_2 emission reduction per metric ton of climate-neutral hydrogen used for the material use of hydrogen in the direct reduction process. The overall factor for the steel industry is a reduction of CO_2 emissions of 25 metric tons per metric ton of climate-neutral hydrogen used when taking into account energy use in heating furnaces and high-temperature processes in further processing.
[19] Ptx Lab Lausitz (2024): 'Feedstock mix for sustainable chemistry' and Meng et al. (2023): 'Planet-compatible pathways for transitioning the chemical industry'.

- in the cement industry, for example, the reduction of the clinker factor and the use of sustainable concrete and building material alternatives,[20]
- in transport, for example, the use of battery-electric vehicles (BEV) for all short journeys and the electrification of long-distance transport (lorries, rail),
- in the energy supply, for example, leveraging the potential for flexibility in the electric power system,
- in decentralised heat generation, the increased use of heat pumps, thermal insulation and renewable heating networks for space heating, which in most cases are more efficient and available from the perspective of the large system scenario studies and lead to significantly lower hydrogen requirements.[21]

For 2030, the total quantity of 94–125 TWh nevertheless constitutes a plausible range.

Table 1

	2030			2035	2040	2045
	Mil. t H_2	TWh[22]	CO_2 emissions reduction (mil. t)	TWh	TWh	TWh
Process industries		**56–82**		**130–180**	**167–250**	**254–402**
Steel industry	0.8–0.9	28–29	23	63	67–73	67–73
Chemical industry[23]	0.6–1.3	21–45	0–3	47–95	73–144	148–283
Other process industries	0.2	7–8	N/A	20–22	27–33	39–46
Transport sector		**33**		**73–74**	**135–137**	**161–186**
Private transport incl. light commercial vehicles	0.04	1.3	0.2	4	8	8
Heavy goods transport (heavy-duty commercial vehicles) incl. buses	0.7	22	4	58	88	88
Refineries	0.05	1.7	0.6	4	2	0
Aviation	0.04	1.4–1.6	0.3	5–6	34–36	60–85
Shipping	0.02	0.7	0.1	1.5	3	5
E-fuels[24]	0.2	6	1.2	N/A	N/A	N/A
Heating market[25]		**5–10**		**N/A**	**N/A**	**125–500**
Energy supply		**0**		**30**	**N/A**	**80–200**
Total		**94–125**		**233–284**	**302–387**	**620–1288**

[20] UBA (2020): 'Dekarbonisierung der Zementindustrie [Decarbonisation of the cement industry]' and Competence Centre on Climate Change Mitigation in Energy-Intensive Industries (KEI) (2022): 'Auf dem Weg zur klimaneutralen Industrie: Zement [Toward a climate-neutral industry: cement]'.
[21] See the meta-studies from Öko-Institut (2024): 'Erdgas Phase-out in Deutschland [The phase-out of natural gas in Germany]' and Rosenow (2024): „A meta-review of 54 studies on hydrogen heating".
[22] The conversion is based on the lower calorific value for hydrogen, therefore 1 million t H_2 corresponds to about 33.33 TWh.
[23] For 2030, it is assumed that the demand of the chemical industry, which has been covered by grey H_2 up till now, will only proportionally be covered by climate-neutral or mostly climate-neutral hydrogen. This means that the data for 2030 also concerns the demand for grey hydrogen. The hydrogen demand identified will be gradually converted to exclusively climate-neutral hydrogen by 2045.
[24] For demands beyond aviation and shipping.
[25] Centralised and decentralised generation.

H2 NATIONALER WASSERSTOFFRAT

THE GERMAN NATIONAL HYDROGEN COUNCIL

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 26 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Katherina Reiche.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

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