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GTP

The Gas distribution Transformation Plan

Report of Results 2022

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1 Management summary

The Gas distribution Transformation Plan (GTP – Gasnetzgebietstransformationsplan), launched in March 2022, is a multi-year planning process for the transformation of the gas distribution networks to climate neutrality. With 180 participating network operators in the first planning round, the majority of network connections in Germany are already represented.

The vast majority of all districts in Germany have municipalities whose gas grids are operated by one of the participating companies.

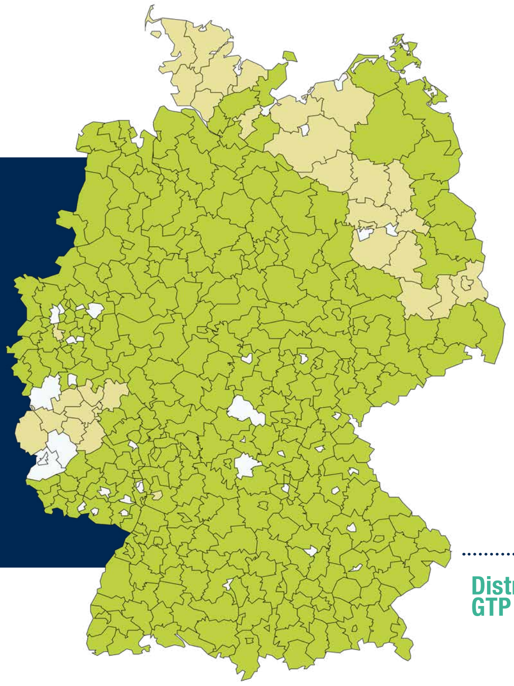
The distribution system operators have analyzed their grid areas in a structured process that took into account their customer needs, the decentralized injection situation, supply by upstream grid operators and the technical suitability of their pipeline grids for hydrogen. These analyses will receive further attention in the following years, with the aim of completing an investment-ready plan by no later than 2025.

Overview of the results:

- The results clearly show that distribution system operators are already planning to convert their grids to hydrogen supply on a large scale.
- Analyses of the pipeline network materials have shown that 95.9 percent of the pipelines are made of the H_2-suitable materials steel and plastic. Only 0.2 percent are unsuitable, the remaining 3.9 percent are being clarified.
- The feedback provided already shows that the majority of the participating grid operators see the first regular use of hydrogen in their distribution grids in the near future – in many parts of Germany already within the next eight years.
- Large-scale conversions to 100 percent hydrogen are anticipated in many cases in the 2030s, due to the time required for the conversion of customer facilities and the planned conversion dates of the transmission system operators' pipelines to hydrogen.
- The majority of hydrogen is expected to be sourced via the transmission system operators. A purchase of (then climate-neutral) methane via transmission pipelines in 2045 is currently only seen by a few distribution system operators, as the availability of hydrogen is currently estimated to be higher than the availability of climate-neutral methane.
- Depending on the region, a long-term and extensive use of locally produced biomethane is also assumed.
- The volume plans show that many network operators are anticipating energy efficiency gains.
- Initial results of the customer analysis show relevant quantities of early decarbonization demand among RLM customers (industry, power plants, CHP).

Outlook: In the years up to 2025, the level of detail in planning will be continuously increased. The technical analysis will be expanded to include further components and systems of the distribution networks. In discussions with customers and municipalities, the requirements in terms of timing and volume will be determined and, in conjunction with the supply situation through the upstream grid operators and decentralized generation, converted into a sound network plan. The guidelines for the preparation of the GTP 2023 will be published in spring.

[a] Based on the DVGW G 410 gas-water statistics; the DVGW G 410 covers 91 percent of the pipelines in the German gas distribution networks. Of the 180 participating gas distribution system operators, 178 have submitted a G 410 report since 2015. Their entries represent 56 percent of the kilometers in the network and 57 percent of the network connections.



180 network operators

In the 2022 GTP process, 180 gas distribution system operators across Germany have filed feedback, and 10 other distribution system operators have reported the start of the planning process without filing for 2022. Together, their networks cover more than half of Germany's network kilometers and network connections [a]. They are distributed across the whole of Germany.

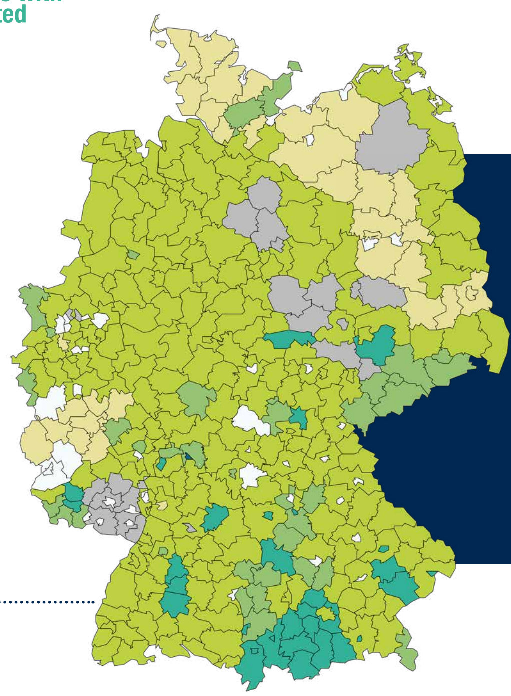
- GTP feedback in 2022
- GTP feedback starting 2023
- No participation to date

Districts in which networks with GTP participation are located

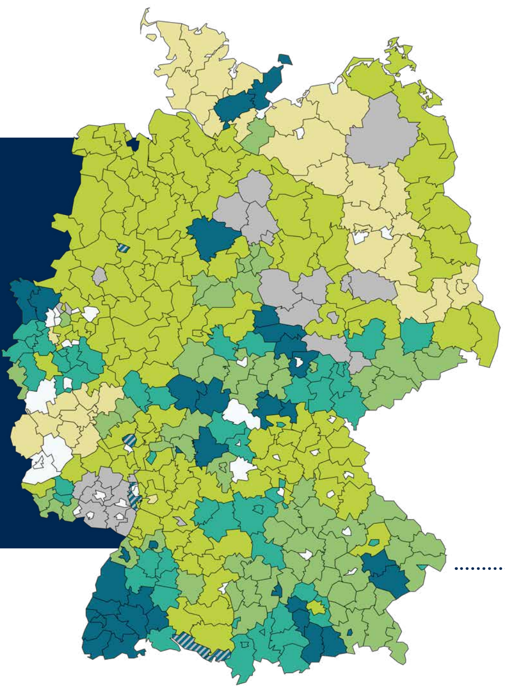
By 2030

the injection of H_2 will begin in large parts of Germany. By 2040, all gas-supplied regions will be reached.

- H_2 by 2030
- H_2 by 2035
- H_2 by 2040
- H_2 by 2045
- No data
- TP feedback starting 2023
- No participation



First H_2 injections



The first 100% H_2-networks

are anticipated to exist in many parts of Germany as early as 2030. Large-scale conversions will take place in the 2030s.

- by 2030
- by 2035
- by 2040
- by 2045
- Mixed gas in 2045
- No data
- GTP feedback starting 2023
- No participation

First 100% H_2 networks/ conversion zones (shown at district level)

2 Introduction

Germany intends to become climate neutral by 2045 and has enshrined this target in legislation. In terms of the situation as it stands today, where 84 percent of the energy we consume annually come from fossil fuels [0], this means we must drop to zero by 2045. However, Germany will continue to need large amounts of energy in the future too, even if we achieve energy-saving successes. Hydrogen and its derivatives, like methanol and ammonia, are ideally suited for storing renewable energy generated in Germany or for importing renewable energy (we currently import around 70 percent of the energy we use [1]. This is because climate neutral hydrogen can be directly produced for example, by means of electrolysis from water and renewable electricity.

With its gas networks, Germany has a highly developed energy supply infrastructure, with 554,500 km of gas distribution networks alone. In addition to half of all households, 1.8 million industrial and commercial customers are connected to these distribution networks [2]. The gas networks supply these customers with natural gas, and also methane. They can, however, be upgraded for the transport of 100 percent climate neutral hydrogen.[3] Today's natural gas supply can therefore be transformed into a climate neutral supply.

With the 'Gas distribution Transformation Plan' (GTP), the H2vorOrt initiative launched a sector-wide planning process in March 2022 that forms the basis for a nationwide hydrogen transformation in the distribution grid. H2vorOrt is an association of now 47 distribution system operators in the German Technical and Scientific Association for Gas and Water (Deutscher Verein des Gas- und Wasserfaches e.V. (DVGW)) in cooperation with the German Association of Local Public Utilities of municipally determined infrastructure undertakings and economic enterprises (Verband kommunaler Unternehmen (VKU)). They pool their expertise with the goal of ramping up the hydrogen economy. The goal of the GTP is to accelerate the transformation of gas distribution networks and to incorporate the individual planning of the network operators into a coherent vision for the whole of Germany. This cooperation, particularly between upstream and downstream network operators, is essential for achieving decarbonization targets. DVGW head office has therefore informed the management of gas companies in the DVGW about the GTP process in a circular and asked distribution system operators to make the necessary preparations for planning the gas distribution network transformation by participating in the GTP.

The urgency of replacing fossil gases in the heating market has become evident to us with the war in Ukraine and Germany's dependency on Russian energy imports. We are seeing a political reaction in the form of accelerated efforts to tap into alternative climate neutral energies for Germany. In particular, the commitment of the Federal Ministry of Economy and Climate Protection to hydrogen imports from Australia, Canada, northern and southern Africa as well as South America and the completion of supply contracts by private companies, like for example, between E.ON and the Australian company Fortescue Future Industries, offer firm prospects for the rapid procurement of significant quantities of hydrogen. At the same time, in a period of inflation and sharply increasing energy prices, we are experiencing how important a socially responsible energy transformation is, one that unites both socio-economic and climate protection factors. Furthermore, companies in Germany need a concrete perspective for how they can begin to or continue to operate their business model in a climate neutral manner as well.

In addition to import planning, the planning of transmission system operators for hydrogen transport is proceeding apace. One example is the 'H_2ercules' project from OGE, which aims to build hydrogen infrastructure from the North Sea to southern Germany by 2030.

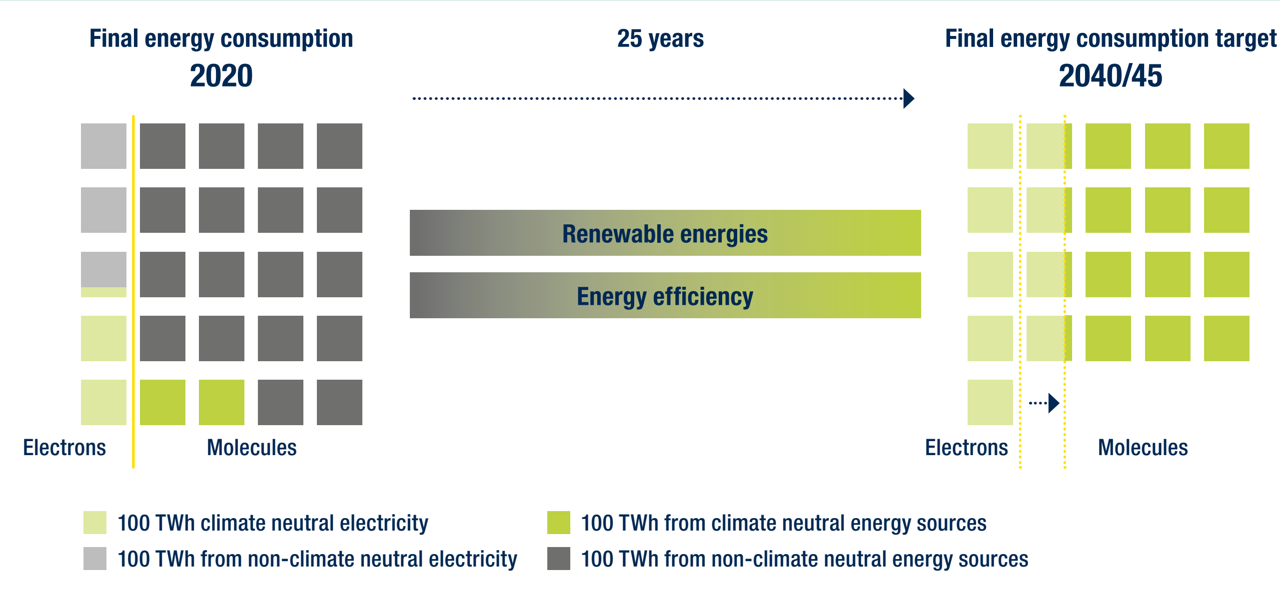


Fig. 1: Final energy consumption 2020 and 2040/45 (based on graphic by: terranets bw GmbH, 2022)

A glance at the final energy consumption of Germany (see. Figure 1) shows that in 2020, around 80 percent of our energy demand was met in the form of molecules [4]. One tile corresponds to an energy quantity of 100 TWh. The ratio of green- and grey-shaded tiles indicates that only a small portion of final energy is supplied in a climate neutral manner at present. By 2040/45, climate neutral final energy will reach to 100 percent, in line with policy objectives.

Overall final energy consumption will reduce through efficiency measures. We will also see an increase in electrons because of significant electrification, although the shift in this figure is to be understood qualitatively. Nevertheless, despite all the successes in expanding electric infrastructure, large quantities of molecular energy will still be needed.

The 'H_2ercules' project has the potential to bring hydrogen supply to vast areas of Germany as early as the end of the 2020s. It is crucial here that the coordination that is already in motion with distribution system operators on the H_2ercules pipelines is ambitiously advanced.

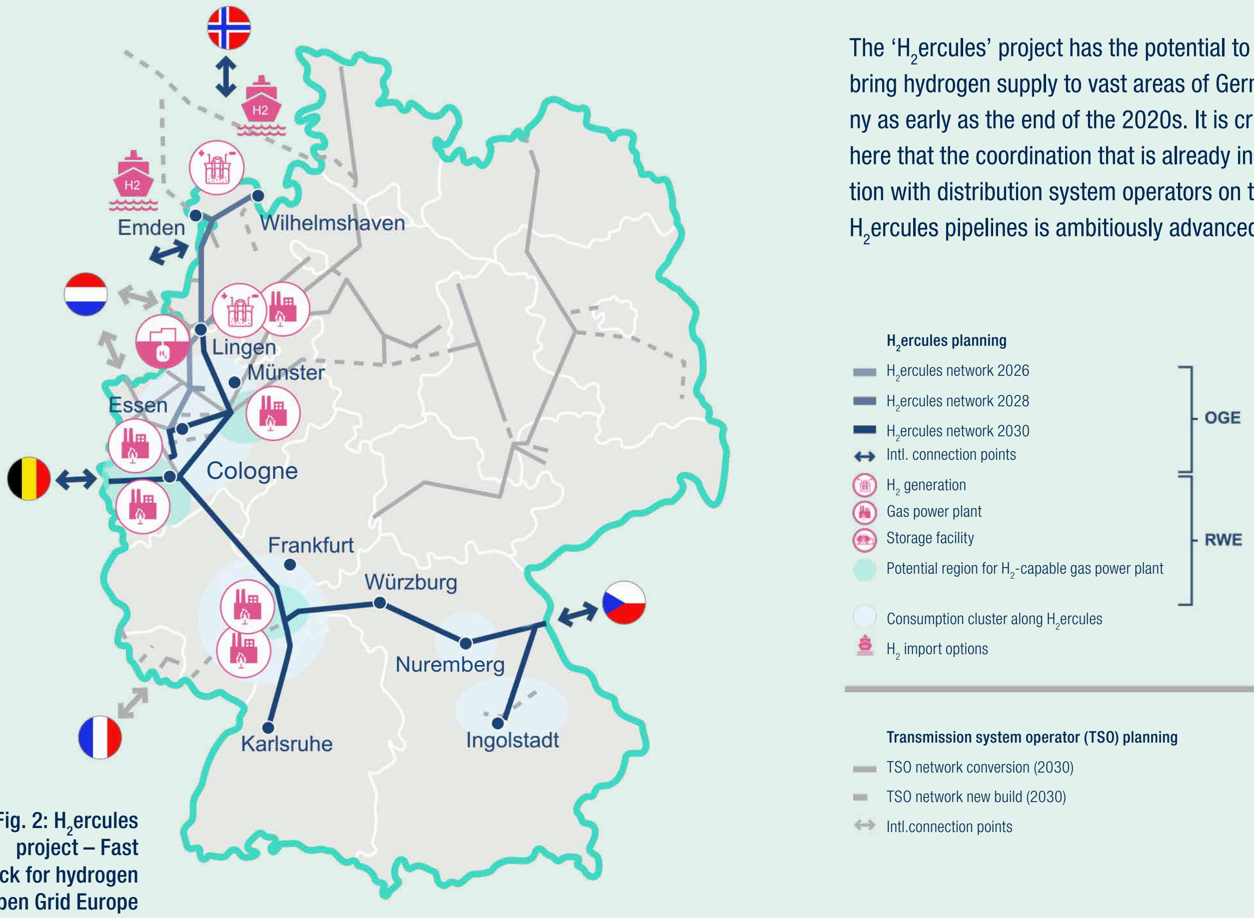


Fig. 2: H_2ercules project – Fast track for hydrogen (Open Grid Europe GmbH, 2022)

H_2 BACKBONE 2032 (TSO GAS 2022)

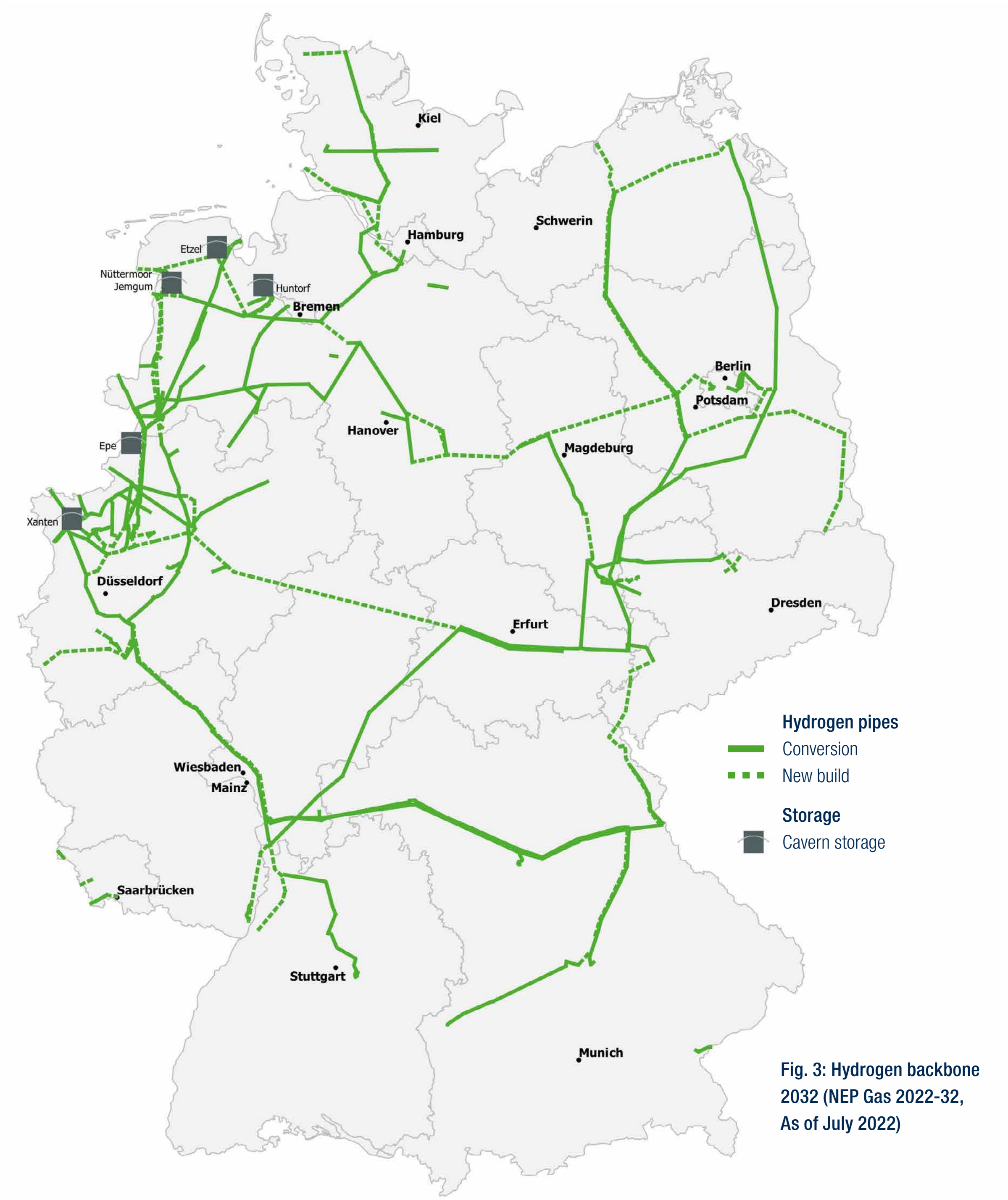


Fig. 3: Hydrogen backbone 2032 (NEP Gas 2022-32, As of July 2022)

How the hydrogen transformation on the distribution network level is being approached in a concrete manner, and what insights were obtained, can be found in the following chapters:

- Chapter 3 looks at the analysis of the customer situation for future supply
- Chapter 4 deals with the feed-in of decentrally produced gases into the distribution network
- Chapter 5 shows how the conversion will be planned both geographically and in terms of scheduling
- Chapter 6 addresses the technical upgrading of the network components
- Chapter 7 provides an outlook on further development

3 Analysis of the customer situation for future supply

With the GTP, distribution system operators become the bridge between customers and the hydrogen backbone

Gas distribution networks supply a large number of customers with molecular energy nationwide. In the future, this is to happen in a climate neutral way. However, it is not just a question of distribution networks. Germany's entire future hydrogen supply must be adapted to the needs of the customers in terms of quantity, output and composition.

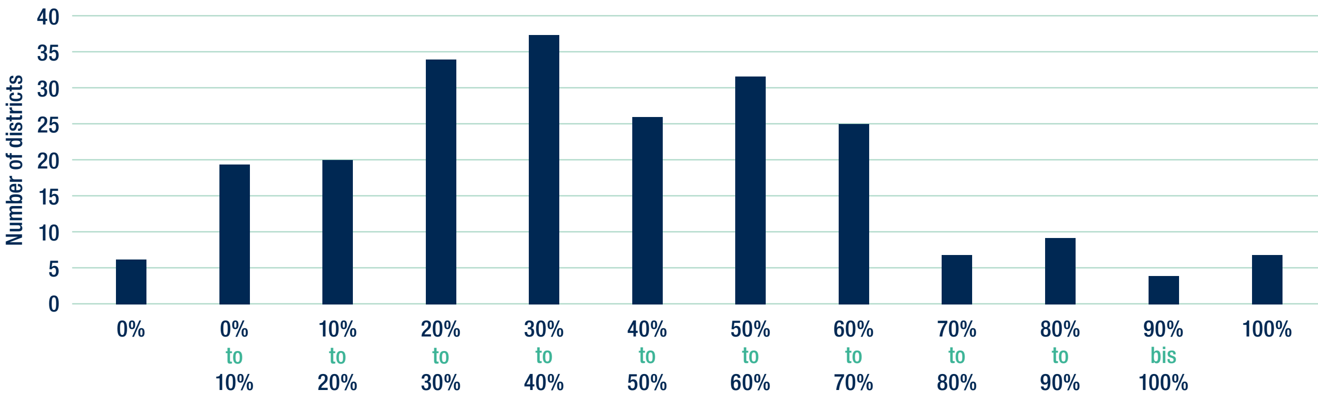
To ensure that this supply is developed in the right way, it is essential that it is rooted in customer needs. Distribution system operators have a central coordinating role here. On the one side of their network, they are connected to the hydrogen backbone of the transmission systems operators, via which hydrogen is transported cross-regionally and internationally to the distribution networks. On the other side, they know their customers and their needs. They can therefore build the bridge needed between supply and demand and ensure that the supply infrastructure is scaled in a way that both satisfies demand and security of supply. Thus, in addition to the transformation of their own networks, the distribution system operators assume the role of central intermediary for achieving a successful hydrogen transformation.

This analysis and the intermediary role form the core of GTP customer analysis. In the current 2022 GTP, assessments are to a large extent, still based on internal customer analyses. At the same time, companies are now beginning an intensive dialogue with their major customers and municipalities. This dialogue, along with discussions with their respective upstream network operators, and thus ultimately also the transmission system operators, form the basis of coherent target-oriented network planning for hydrogen.

German gas distribution networks supply a large proportion of industry, business and households

In Germany, currently 1.8 million industrial and commercial enterprises as well as around half of all households are supplied by gas distribution networks [5]. Together with gas-based electricity generation (particularly combined heat and power), 742 TWh – equivalent to more than 75 percent of Germany's natural gas – was supplied through the distribution networks in 2020 [6].

RLM annual volume in total annual volume per district*



* Customers with consumption metering (registrierende Leistungsmessung (RLM)) are major customers with a consumption of 1.5 million kWh per year, such as industrial companies or large commercial enterprises. The diagram is based on 109 assessable responses with data on 218 districts. Quantities for downstream network operators were not taken into account. There may be additional networks of other gas network operators in the districts that either have not provided feedback in general, or have not reported on this issue, or their feedback was inconsistent. Over the coming years, we expect to receive more comprehensive responses that will corroborate this picture further.

Analysis of the feedback on the GTP clearly shows that the industry is highly distributed and mixed with private residential buildings. That means it is not primarily found in clusters. This structure makes it clear that a separate hydrogen supply for industry is not constructive, instead hydrogen must be developed on a broad scale nationwide.

The supply of hydrogen and other climate neutral gases is highly relevant for all customer groups

In many cases, industrial processes require high temperatures (74 percent[7] of processes need over 500°C). This level of heat is almost exclusively generated by fossil fuels and can potentially be achieved through hydrogen and other climate neutral gases. It is often not technically possible to carry out these processes with electricity.

However, hydrogen is not only highly relevant for the industrial sector. For buildings especially, we are facing a decarbonization challenge of huge proportions. The demand for molecular energy carriers is particularly high in the winter half of the year and will not be replaceable on this scale through other energy forms on a widespread geographical basis. The expansion of the electricity and district heating networks will not solve this, as it encounters both economic limitations and feasibility constraints in the remaining timeframe. For the distribution of the required energy quantities, a mixture of molecular energy carriers (hydrogen, biogas, synthetic methane), electrical applications (heat pump, direct electricity heat), district heating and energy-saving measures will be necessary. Developments in terms of climate and regional demographics could give rise to further reductions in energy demand.

With regard to adapting buildings, we will not have the time required for this enormous task that would be socially necessary. With the gradual transformation of the natural gas network into a hydrogen network, a diverse stock of 20 million buildings in Germany can become climate neutral, without having to create new infrastructures at record speed around the country.

Using hydrogen in the heating sector and the transformation of the gas distribution networks into hydrogen networks also allows building owners more freedom to achieve climate neutrality for their own, particular buildings. Without hydrogen, there is no market alternative to electricity (wooden pellets cannot sustainably cover the energy quantities required).

The decarbonization of the energy supply must meet the large power requirements of heating supply in winter.

The advantages of hydrogen energy supply come particularly to bear in winter, when the heating demand is at its peak.

The gas networks, as opposed to the electricity networks, are designed for seasonal fluctuations. Furthermore, because electricity generation does not seasonally adjust upwards at the same time as heating demand, high-performance storage technology is necessary, along with a network infrastructure designed for the heating periods, regardless of the heating technology.

Hydrogen is on the one hand, a storage medium for nationally produced or imported renewable energies and can on the other hand, can be stored in large quantities in converted gas storage facilities. Thus, in the future, the high energy demand during the winter heating period can be sufficiently covered by hydrogen in the same way natural gas is used today.

Initial findings of the bottom-up study for the National Hydrogen Council[8]

This June, commissioned by the National Hydrogen Council, the Fraunhofer Institutes for Solar Energy Systems ISE and for Energy Economics and Energy System Technology IEE presented the preliminary findings of a bottom-up study on pathway options for an efficient and socially feasible decarbonization of the heating sector. The initial results show that top-down studies cannot reflect the full spectrum of decision criteria, objectives, and economic framework conditions that in reality are relevant and decisive for the individual players and decision-makers on the ground. Initial results indicate that the needs of industry and of local power plants are difficult to meet without maintaining the necessary gas distributions networks and converting them to H_2. Initial calculations for concrete case studies also suggest that at present there is no robust reason to exclude the option of repurposing gas distribution networks for hydrogen use to heat individual buildings generally or for any given individual case. The decision should be determined by municipal heat planning, without excluding any technology option.

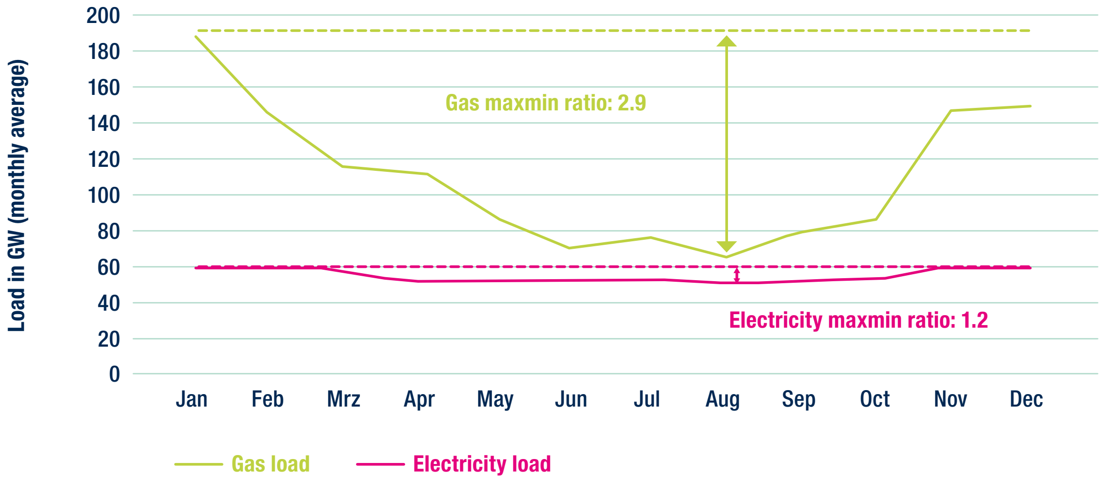


Fig. 4: Monthly comparison of electricity and gas demand (load in GW) in average cold example year (2017); Source: DVGW (2022): Resilient strategies for a sustainable heating transition with climate-friendly gases. A sustainable heating market; Part 2

Source: Frontier Economics based on IEA Statistics and ENTSO-E Transparency Platform

Note: The maximum ratio reflects the relationship between the absolute monthly maximum and the minimum, each calculated separately for gas and electricity loads.

"The H_2 option ensures that the medium-term (from 2030) and long-term climate targets in industry and energy generation (district heating) are achieved and expands the solution space for the decarbonization of private households. A demand-based expansion or conversion of the necessary infrastructures is urgently needed for this purpose. Supplying residential buildings with H_2 should not, in principle, be excluded and should be retained in the solution space.

Along with renewable electricity, H_2 is an important component for the decarbonization of the heating market and for heat in industrial processes in particular, is indispensable.[8]"

Transformation emerges from customer needs and from availability via the backbone

Through their power requirements as well as their requirements in terms of gas composition (hydrogen, methane, mixed gases), gas network customers influence the path to climate neutrality of the respective gas distribution network. In addition, the amount of time needed for achieving climate neutrality varies from customer to customer. For example, CHP plants and some industrial customers in the supply chains will have to become fully climate neutral earlier, or might need longer transitional periods due to technological factors. Some municipalities and federal states have also set themselves the goal of achieving climate neutrality long before 2045. But the feasibility of an earlier date is also dependent on the supply and distribution of hydrogen as a climate neutral, material energy carrier. That's why the cumulated customer needs must be communicated to the supplying transmission system operator transparently and at an early stage, so that a timely network transformation can begin.

Initial results of the analysis of acute decarbonization needs of RLM customers

In the 2022 GTP, the analysis of acute decarbonization needs of RLM customers was based on internal considerations of the network operators. From 2023, this is to be carried out on the basis of close customer discussions. Assessable evaluations were submitted by 30 network operators in the 2022 GTP for this purpose. By 25 network operators, customers were also categorized according to drivers of decarbonization: 'EU-ETS', 'EU taxonomy', Market' as well as 'Other', whereby customers could be assigned to several categories.

The following picture emerged:

Total*	Reports with breakdown**	EU-ETS	EU-Taxonomy	Market	Other	Reports without breakdown
42,5 TWh 1.200 customers 30 network operators 76 districts	35,5 TWh 900 customers 25 network operators 63 districts	70%	12%	12%	14%	7,2 TWh 300 customers 5 network operators 15 districts

* In some cases, several network operators are active in the same districts.

** Since a customer can be allocated to several categories, the sum of the percentage totals more than 100 percent.

Table: Acute decarbonization needs of RLM customers

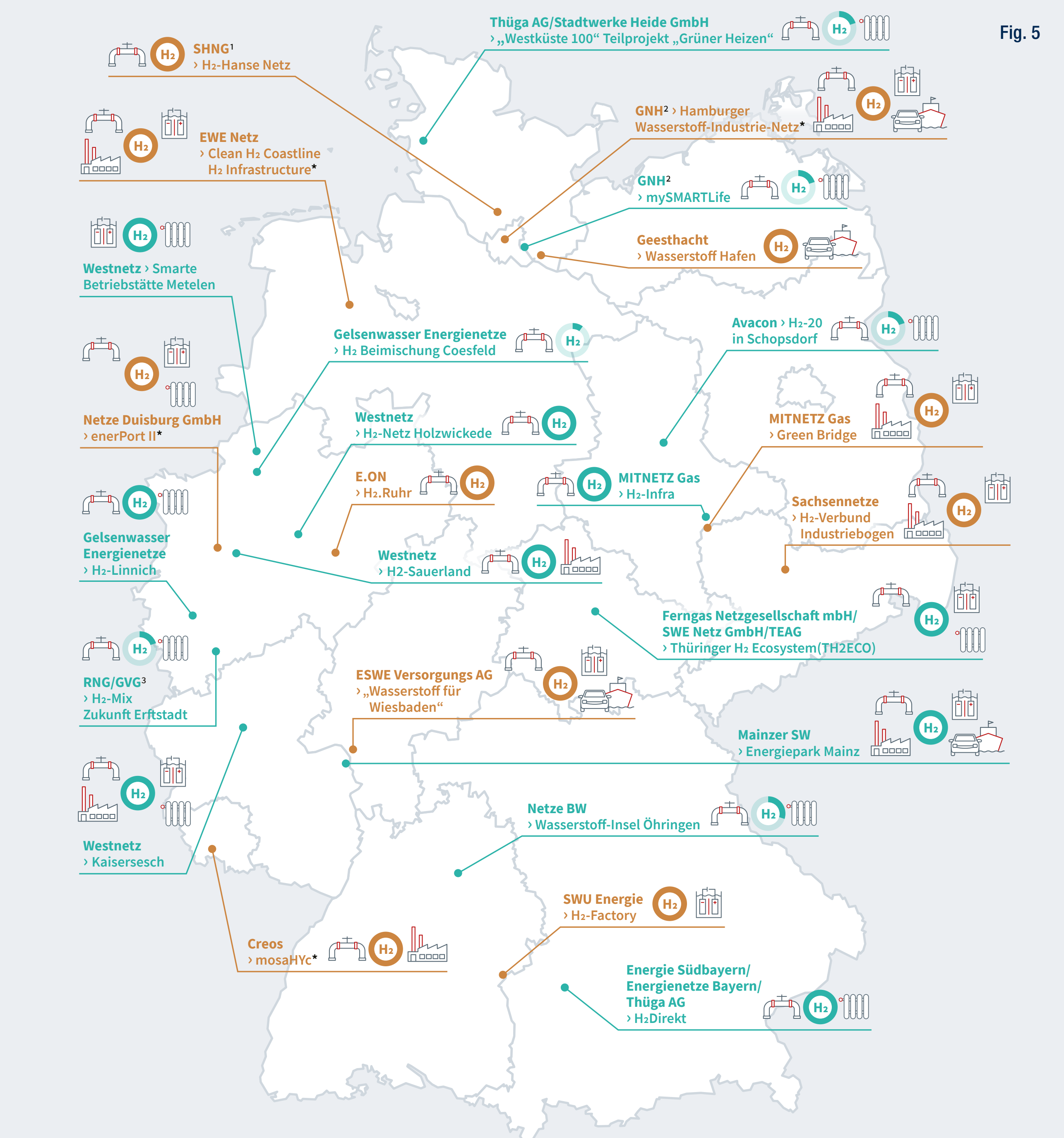
Among the remaining participants, it is clear that as expected, distribution system operators must acquire additional knowledge over the course of the customer dialogue in the GTP process. In addition, the relationship between network operators and RLM customers must develop even further into joint planning. The development of this knowledge is the core of a demand-oriented network transformation and thus constitutes the core of the GTP. Furthermore, it is still not clear to many network operators what the exact impact of the latest and still partially in-progress EU regulation (EU taxonomy, ETS revision) will have on their own customers. At the same time, one can already see that the overall amount required of 42.5 TWh is a very relevant magnitude for 30 network operators, and it demonstrates the urgency with which this topic must be addressed.

Over the coming years, we expect groundbreaking results and advances to be made as well as strongly increasing feedback numbers as a result of this process.

4 Injection of decentrally produced climate neutral gases into the distribution network

BDEW (2022): Overview of decentralized hydrogen projects with a focus on the distribution network, based on a joint inquiry by associations BDEW, DVGW and VKU in the framework of preparing the hydrogen report in accordance with §28q EnWG.

Fig. 5



The image is based on a joint inquiry by associations BDEW, DVGW and VKU.

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Project being implemented until 2024
Project in planning
Admixture of hydrogen shown proportionately as a percentage
Network | H_2-generation | H_2 mobility | Industry | Heat

* approval pending
[1] Schleswig Holstein Netzgesellschaft, [2] Gasnetz Hamburg, [3] Rheinische NETZGesellschaft mbH/GVG Rhein-Erft GmbH

An important factor in transformation planning

Within the framework of the 2022 GTP, the decentralized network injections into the gas distribution network were collected and analyzed with respect to an eventual hydrogen transformation. Only guaranteed injection amounts for biomethane or hydrogen were taken into consideration or currently completed network connection contracts. How long the current injection operation can be assumed to continue or when an injection into the gas distribution network is planned, was also recorded.

Status Quo – Injection of hydrogen

In recent years, the first H_2 injection systems materialised in which hydrogen was mixed into the natural gas grid. Whether on a small or industrial scale, blending or 100 percent conversion, research-based or ready-for-use in practice, the selection of over 30 projects on the distribution network level carried out in the 2022 hydrogen report gives an impression of the multifaceted decarbonization activities currently carried out by the gas distribution system operators distributed across the whole of Germany[9]. The knowledge gained there can be transferred to other gas network operators or municipal utilities in the future.

At locations where customers need methane as a material for their processes or the network area is dominated by biomethane, there is furthermore the possibility of converting the hydrogen into climate neutral methane (RE methane) and injecting it into the gas distribution network. This is facilitated through methanization with a climate neutral CO_2 source, like a biomethane processing plant.

Because of the anticipated increase in the amount of decentralized injection plants injecting climate neutral gases into the gas distribution network, the injection situation between transmission system operators and distribution system operators will change. There will be individual areas across Germany that will be supplied with climate neutral methane (biomethane, RE methane) over the longer term. Another advantage of these methane based areas is that the existing gas infrastructure can continue to be used with little or no investment.

Status Quo – Injection of biomethane

The injection of biomethane into the gas distribution network is a technique that is already applied today. At the end of the 2000s, the first biomethane injection facilities began operation, and many of these plants have been since connected to the gas network. There are almost 9,700 biogas plants in Germany, run on an installed electrical capacity of around 5,700 megawatts[10]. The majority of the biogas that was generated will still be used for direct, on-site electricity generation. Only a small portion will be processed into methane in approx. 240 plants and fed into the natural gas network. In the framework of the GTP, 122 existing plants were reported and a further 28 are at the planning stage. In the future, it can be expected that with the expiry of compensation based on the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG), more biogas plants will cease decentralized electricity generation and through processing biogas into biomethane, make this climate neutral gas available to the general public via the gas distribution networks. From a regional perspective, there is huge potential for injecting biomethane, especially in Schleswig-Holstein, Lower Saxony, Baden-Württemberg, Bavaria and the former lignite regions (Rheinisches Revier, Lausitz).

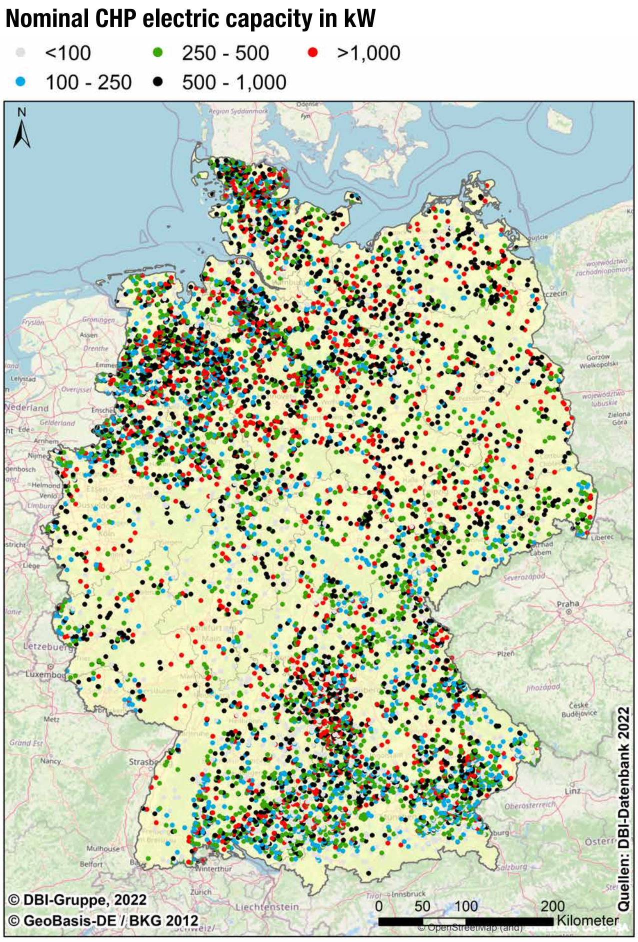


Fig. 6: Nominal CHP capacity of the currently EEG-funded direct biogas power plants (DBI-Gruppe, 2022)

Figure 6: Nominal CHP capacity of the currently EEG-funded direct biogas power plants (DBI-Gruppe, 2022),
Figure 7: Capacity of existing biomethane processing plants.

The need to ramp-up the generation and use of renewable gases to the maximum possible extent is greater than ever. This ensures that dependency on fossil natural gas imports can continue to be further reduced very rapidly and in a climate-friendly way, while guaranteeing supply, affordability, and thus social feasibility. By retrofitting the existing biogas plant park, large quantities of biomethane can be produced relatively quickly. Where necessary, raw biogas quantities of smaller biogas plants can also be transported via gathering lines to a central processing plant.
The potential of previously unused residual and waste material and other generation processes such as the gasification of solid biomass, can be added to this. The latest studies recognize the possibility of exploiting potentials of over 100 TWh in the medium term through the retrofitting of existing plants [11]. There are several suppliers participating in the GTP who currently have a large number of queries in relation to connecting existing plants to the gas network.

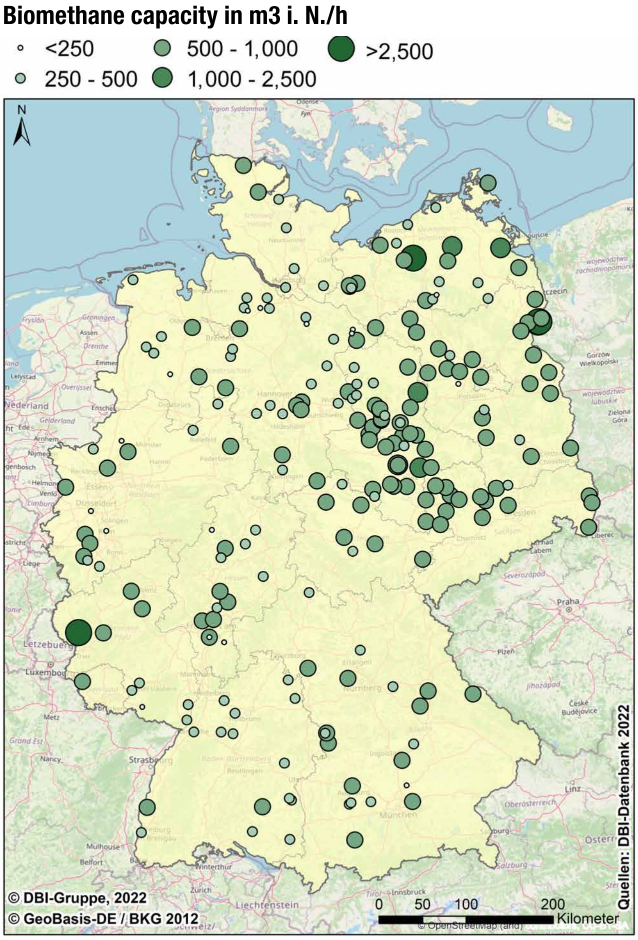


Fig. 7: Capacity of existing biomethane processing plants (DBI-Gruppe, 2022)

The supply of climate neutral gas networks with biomethane can continue to be supported by using the climate neutral CO_2 captured during biogas processing for the methanation of climate neutral hydrogen, through which even more climate neutral methane can be produced.

Adding biomethane into a hydrogen-only network would in principle be possible in terms of network engineering, however the terminal equipment on the customer side must be capable of processing mixtures consisting of e.g., 90 percent hydrogen and 10 percent biomethane. Alternatively, biomethane can be incorporated into a pure hydrogen network by generating hydrogen from biomethane. Ideally, this happens through a process that no longer allows the carbon in the biomethane to escape into the atmosphere. This is the case for example, with so-called pyrolysis, which generates hydrogen from methane and captures carbon in solid form. Because biomethane is already climate neutral, negative emissions are generated during the pyrolysis process, as the CO_2 captured from the air by the source plants remains bound in material carbon and no longer returns to the atmosphere. The generation of negative emissions is a great opportunity to finally bridge the gap to full climate neutrality, since this way certain emissions, that otherwise hard to avoid, can be offset. In the 2022 GTP, only data on H_2 injection was collected where the implementation of which is largely assured. 37 H_2 injections were reported. In 14 of these cases, H_2 was produced from biomethane in the course of converting an area to H_2.

Outlook

Another objective of the future GTPs (from 2023) will be to identify suitable locations for decentralized injections (biomethane or hydrogen). Equally, areas should be noted that could be transformed at an early stage into a local, climate neutral supply on the network side because of their existing local injections or generation (biomethane or locally produced hydrogen).

In the case of a full conversion of a conversion zone to H_2, it must be checked separately how this can be implemented with an existing biomethane injection. Potential solutions are to be worked out for these cases in the framework of the technical analysis.

5 Planning the hydrogen transition

Transformation must be planned in terms of quantity, space, and time

In terms of analyzing capacity requirements, the subdivision of the distribution networks into so-called 'conversion zones' was a significant result of the transformation plan for gas network areas. Conversion zones are defined as subnetworks that are independent in terms of network hydraulics and because of their size, allow block-by-block conversion to hydrogen or other climate neutral gases. They form the basis for future specification of transformation planning. Their scope was defined on the basis of the respective official municipality codes. Therefore, they can be located in one or more districts, and equally one district can contain multiple complete or partial conversion zones.

The analysis shows how hydrogen demand will develop among the participating companies.

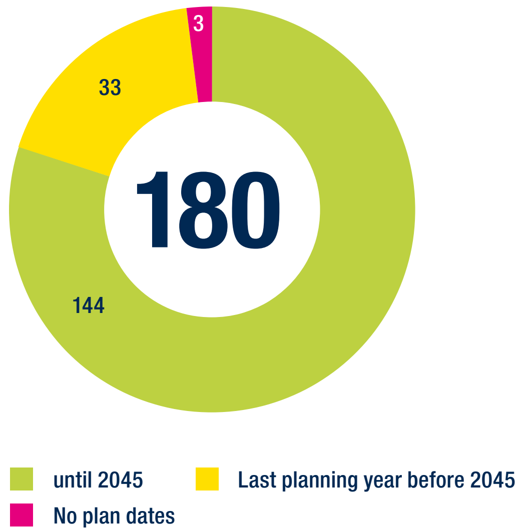
The first shifts in capacity requirements from natural gas to hydrogen will already take place before 2030. This demonstrates that many participants assume an ambitious transformation of their networks to climate neutrality .

For some network operators, the necessary capacities for supplying customers is also expected to decrease. This is the case for example, where through alternative supply solutions, like for example, local district heating, are used as a substitute for current natural gas consumption. Furthermore, many network operators are anticipating gains in energy efficiency. In this respect, alternative decarbonization options are very specifically taken into account in the GTP. The GTP can provide a good basis for municipal heating planning and should be closely coordinated with this.

First results of quantity planning

As part of the capacity analysis, time sequences for the delivery of methane and hydrogen from upstream network operators were recorded for every conversion zone of a network operator. Local injection of hydrogen has been addressed in the previous chapter.

Planning horizon of the GTP



Planning horizon

Of 180 distribution system operators, 144 have submitted plans until 2045. 33 had shorter planning periods, 3 didn't report any time sequences.

Distribution system operators that have not yet prepared a plan until 2045, provided the following explanations, among others:

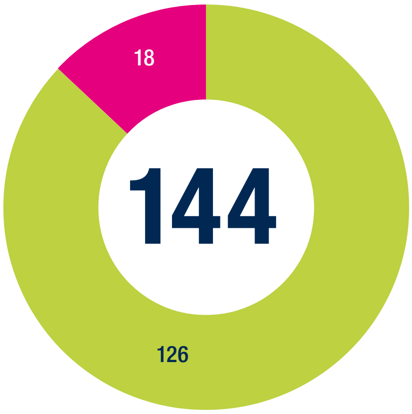
- Planning could not be completed before the GTP 2022 submission deadline
- No statement yet received from the upstream network operator
- Uncertainty

For subsequent years, we assume that the share of complete plans will increase, because the planning process will then have have been in place for some time and coordination as well as planning of the German backbone continues to progress. In addition, uncertainties will ease over the course of general efforts to implement climate neutrality.

Planning and beginning H_2 injection

Of 144 distribution system operators with complete plans, 126 plans for hydrogen have been prepared and 18 with methane-only supply.

Share of GTP reports with H_2 planning



H_2 planning reported
No H_2 planning in 2022 submission

Distribution system operators who did not prepare any hydrogen planning commented the following, insofar as they provided an explanation:

- No statement from the upstream operator yet received
- Uncertainty

Here too, we assume that in subsequent years, greater detail will be provided, also with regard to climate neutral methane, where applicable.

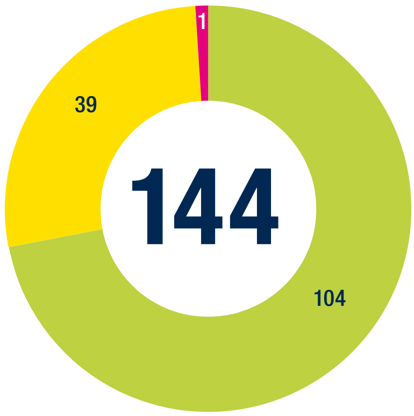
From the 126 distribution system operators with H_2 plans, almost half report the first H_2 injection by 2030 (rounded to full percentages in each case):

- 25 percent begin injection by 2028
- A further 23 percent by 2030 (48 percent total)
- A further 17 percent by 2032 (64 percent total)
- A further 14 percent by 2035 (78 percent total)
- A further 19 percent by 2040 (98 percent total)
- A final 2 percent by 2045 (100 percent total)

The end of methane supply

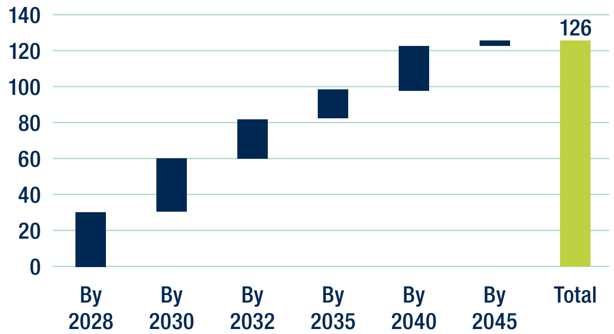
Of 144 distribution system operators with complete plans, 104 will no longer use methane from upstream network operators. 39 will continue to have a methane supply, with one single network operator not submitting any methane plan. Together with the 18 distribution system operators with methane-only supply (see above), this totals 21 distribution system operators that plan to have climate neutral supply with both methane and hydrogen in 2045.

Share of GTP reports with CH_4 end in the planning period

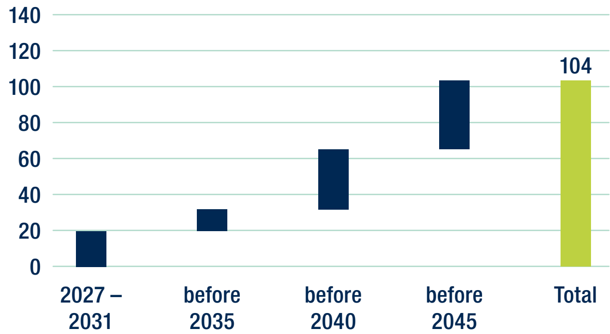


CH_4 ends by 2045 at the latest
Not specified
CH_4 use in 2045

Beginning of H_2 injection



Last year of CH_4 supply



Of the 104 distribution system operators that no longer distribute CH_4 from upstream network operators in 2045, almost a fifth will already stop using methane before 2032 (rounded to full percentages in each case):

- 9 percent before 2032
- A further 13 percent before 2035 (32 percent total)
- A further 32 percent before 2040 (63 percent total)
- A further 37 percent before 2045 (100 percent total)

The use of biomethane that is generated locally in the network area remains unaffected by this. Furthermore, it is important that the evaluation pertains to all networks of a network operator, i.e., when the last conversion zone has been converted. In many cases, the methane supply in one part of the conversion zones of a network operator has already ceased considerably earlier.

In addition to procurement through upstream network operators, local, decentralized generation of hydrogen will also be depicted in the coming maps, to the extent that it is ensured according to the current state of planning and on a scale relevant to the area supply.

The maps are presented at level of districts and independent cities (NUTS-3). Here, districts have been colored according to the first conversion zone that intersects it and fulfills a criterion.

Figure 8 shows the **beginning of the first H_2 injection on the district level**. It can be observed that in many districts, there are whole or partial conversion zones where the respective operator already plans to use H_2 before or in 2030. However, it may be the case, that there are full or partial conversion zones in the same district, that begin using H_2 later.

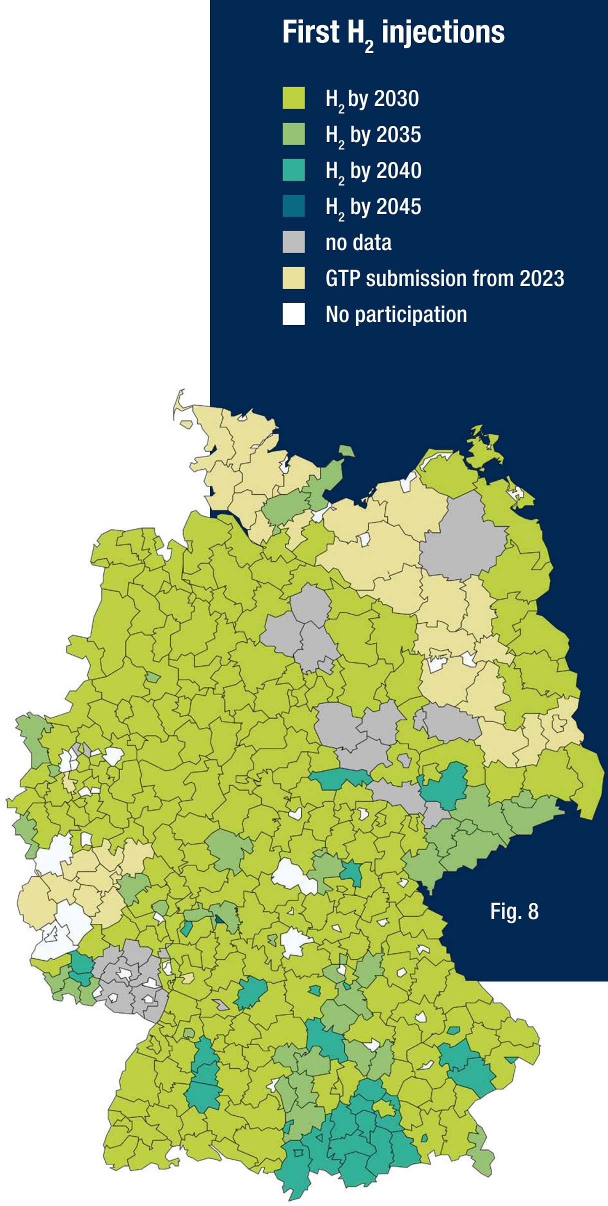


Fig. 8

Figure 9 shows the first occurrence of **100 percent H_2 networks on the district level** [b]. It can be noted that in many districts containing whole or partial conversion zones, the respective operator envisages operation with 100 percent H_2 up to or including 2030 or 2035. We also see a considerable portion of districts containing entire or partial conversion zones that do not anticipate conversion to 100 percent H_2 until after 2035. In addition, we are seeing districts with conversion zones envisioning a climate neutral mixed gas supply in 2045. The potentials for biomethane, which are in part, very extensive, are not taken into account in this depiction.

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[b] 100% H_2 networks in the context of this evaluation are conversion zones procuring H_2 from upstream network operators, but not CH_4. Further networks could exist in the same districts that are not yet transformed.

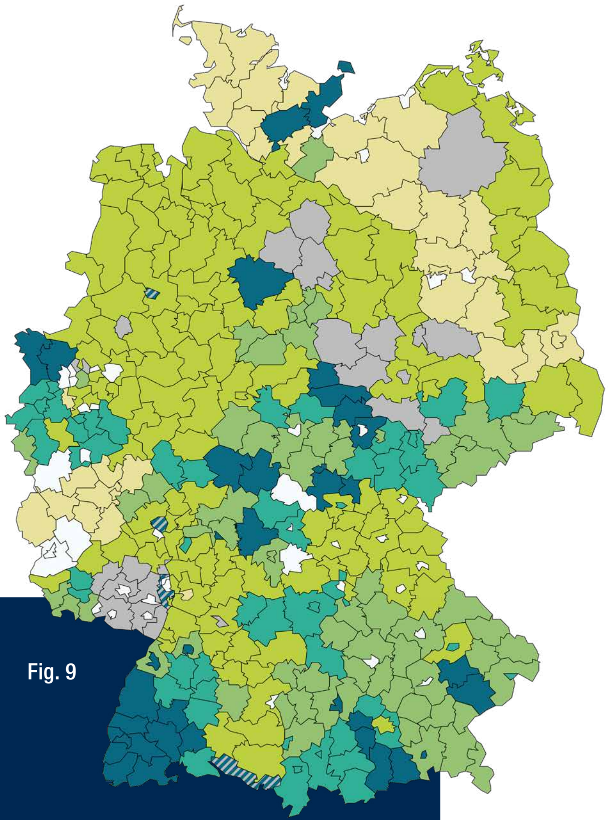


Fig. 9

First 100% H_2-network/ conversion zones (represented on the district level)

- by 2030
- by 2035
- by 2040
- by 2045
- Mixed gas in 2045
- No data
- GTP submission form 2023
- No participation

The graphs show that the first H_2 injections are often already planned for 2030, with 100 percent conversion however, occurring at a later date.

The conversion schedule that has been calculated makes it clear that the transformation of the gas distribution networks is possible in principle in line with policy targets, and it potentially might happen even earlier. Furthermore, the results show that according to the analysis of the local conditions, the vast majority of the distribution system operators intend to upgrade their networks for hydrogen transport. From purely a network perspective, upgrading to 100 percent H_2 readiness is also possible before 2030. However, the necessary investment required is currently not eligible from a regulatory point of view and future ownership issues remain unclear [12].

Good coordination between all network levels is the basis for a successful transformation

These maps depict the first communicated planning status over the course of the GTP process which spanned several years. In subsequent years, the plans will be further specified and uncertainties reduced through dialogue with the transmission system operators, customers and municipalities. In addition, it can be expected that the level of detail will continue to increase through higher participation rates by network operators in Germany. Through the data created in this way, the ramp up of the hydrogen economy will be made possible through ever more detailed individual planning over the coming years.

In all cases however, it must be ensured that the necessary amount of hydrogen is actually provided in the projected annual tranches. As the GTP process evolves, continuous coordination of the conversion years is needed between connected distribution system operators and the upstream transmission system operators in order to optimize the overall conversion procedure from an economic standpoint. This is where the GTP of the distribution system operators and the development of the H_2 backbone of the transmission system operators intertwine and develop into a coherent vision for the German climate neutral gas infrastructure. The objective of the GTP is to solidify the planning by 2025 to such an extent that it becomes feasible for investment.

In addition to integrating into the H_2 planning on the basis of the hydrogen report in accordance with EnWG §28q, it is therefore also necessary to consider the potential hydrogen requirements in the network development plan (Netzentwicklungsplan – NEP) in order to be able to cover the capacity requirements of distribution networks in future.

6 Establishing H_2-readiness: Technical upgrading of the network

The uninterrupted transition from natural gas to hydrogen requires technical preparation

The gas infrastructure transformation process is aiming to be able to guarantee climate-neutral operation with hydrogen, bio-methane and synthetic gases by 2045 at the latest, and in some of the German federal states this is even expected to be achieved by 2040.

An evaluation of the entire supply chain must be conducted for the operation of gas infrastructures and hydrogen [c] applications. In addition to assessing the technical components for their suitability for use with hydrogen and their interconnection, this also includes the organizational requirements in the companies involved.

Figure 10 shows the different dimensions that must be taken into account when considering H_2-readiness. For each dimension, the necessary prerequisites must be defined in order to ultimately ensure overall H_2-readiness when combined. The H_2-readiness of the infrastructure (from the component level to the gas infrastructure) is more technical than that of the adjacent dimensions.

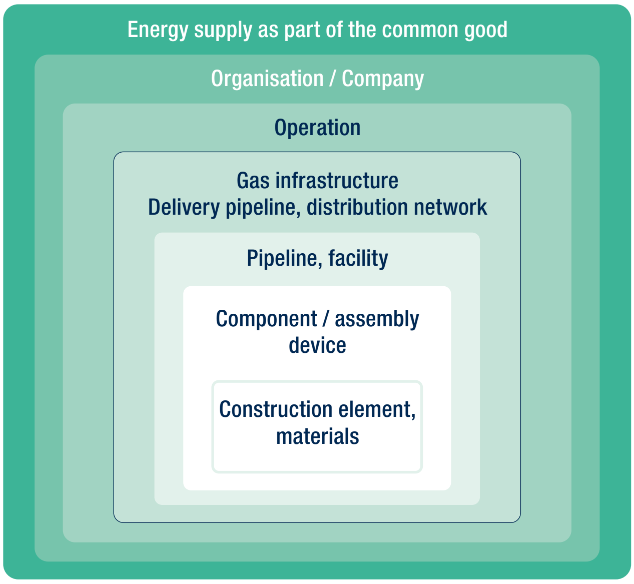


Figure 10: Dimensions for the consideration of H_2-readiness (DVGW e.V., 2021)

Once the fulfilment of the necessary criteria can be demonstrated for the existing gas infrastructure, it is ready for operation and usage with hydrogen, in other words, H_2 ready.

For the initiation of the H_2-readiness assessment process according to Figure 10, the distribution system operators in the GTP 2022 have commenced with the core element in order to evaluate the suitability of the pipeline materials under the respective operating conditions.

This involved reporting the inventory data for gas pipelines, network connections and gas installations in accordance with DVGW Code of Practice G 410 "Inventory and Event Data Collection Gas" ("Bestands- und Ereignisdatenerfassung Gas").

In the following years (2023 – 2025), parts, components, assemblies and devices, among other things, are to be recorded and evaluated with the help of the H_2 database of the DVGW, which is currently being established. This database will contain information on the H_2 readiness of all gas infrastructure components. It will encompass the current state of technology and manufacturers' declarations and will therefore allow network operators to check their own installed components for H_2-readiness in the future. The launch of the database in a first expansion stage is planned for the end of 2022 (the database is not focused on Germany alone, but has international scope and will gradually be available in other languages).

Extensive technology analyses within the scope of the GTP provide the basis for evaluating the physical-technical aspects of the H_2-readiness of the gas infrastructure. This is to be completed by 2025 at the latest.

In a recent study by the DVGW, comparatively low conversion costs totaling approx. 13 – 17 billion euros by 2045 were calculated for the timely and complete achievement of H_2-readiness for the entire German gas distribution network. [d, 13, 14]

[c] According to the 5th gas family of DVGW Code of Practice G 260 "Gas properties".

[d] In comparison, the annual Renewable Energy Sources Act (EEG) feed-in tariff has amounted to 10-15 billion euros per year over the last 10 years. [14]

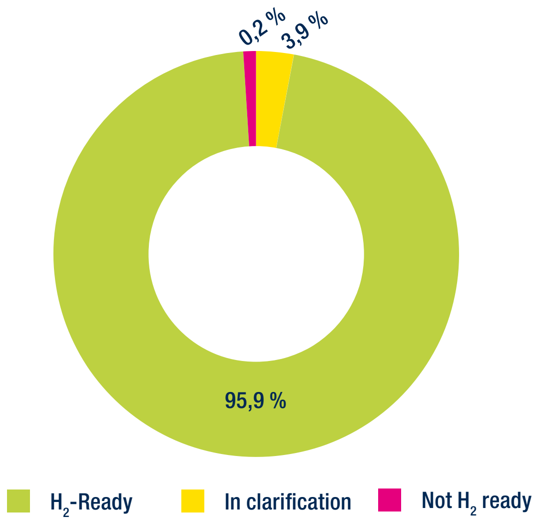
The state of research

Associations, particularly the DVGW, institutes, manufacturers and energy supply companies have conducted numerous research projects and initiatives on H_2 injection possibilities and the H_2 compatibility of materials, parts and components of the existing network in recent years.

Not all questions have been fully clarified to date, and numerous studies and investigations are still underway. But despite this, it has already been confirmed that the gas distribution networks are, for the most part, suitable for the transformation to hydrogen. The results so far show only a very small number of parts/components that cannot be operated with pure hydrogen for material-technical or operational reasons. Furthermore, the customary high stability and reliability of the gas supply are not impaired by the transport of hydrogen. These positive results have been and will continue to be verified by practical tests.

Likewise, there is no evidence to suggest that the very high longevity of the infrastructure components will be impaired in practice in hydrogen operation.

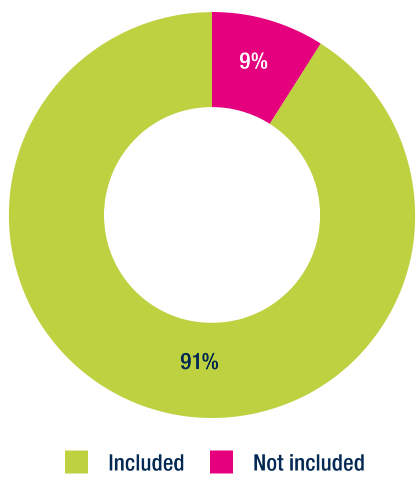
Pipeline network material



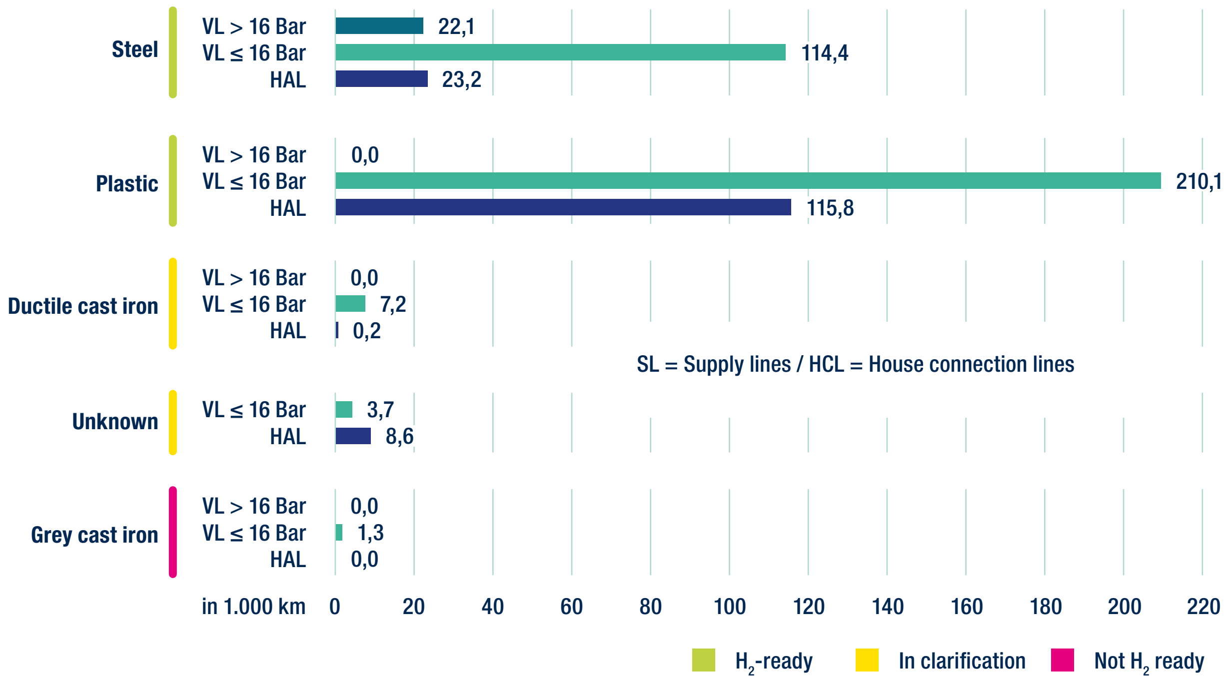
95.9 percent of the pipelines in the German gas distribution network are made of hydrogen-compatible materials

In recent years, German gas distribution system operators have reported material data on a total of 506,584 km of pipelines (grid connection lines and main lines) via the G 410 portal. Figures from the Federal Network Agency show the total length of the German gas distribution network is 554,500 km [15]. According to the most recently reported data sets [e], 95.9 percent of the pipelines are made of H_2-compatible steel or plastic. A further 3.9 percent are listed in the statistics as ductile cast iron or unknown. Only 0.2 percent are made of grey cast iron and thus a material that would first require replacement before the corresponding network section could be converted to hydrogen.

Share of DVGW gas-water statistics coverage of the 554,500 km gas distribution network



[e] In cases where no report was submitted in 2022, the most recently reported data set was used. No data prior to 2015 was taken into account. The evaluation therefore covers 91 percent of the German gas distribution network kilometers. It can therefore be assumed that it is representative for the entire network



Gas pipeline materials according to gas-water statistics G 410

With a total of 325,888 km and a share of 64 percent, plastics make up the majority of the materials deployed in the gas distribution network. In addition to numerous confirmed manufacturer declarations and studies by the DBI, DVGW and other institutes (see Figure 11) and companies, the Kunststoffrohrverband e.V., the German association of the plastic pipe industry, and TEPPFA, the European association for plastic pipelines, have each confirmed in statements, that the materials PE63, PE80, PE100, PE100-RC, PA-U12 and other plastics (e.g. PVC) are suitable for the distribution and transport of hydrogen up to 16 bar.

For the majority of the steel pipes used, research projects (see Figure 11) and industrial gas regulations for hydrogen pipes, such as ASME B31,12 and EIGA 121/14, have proven their long-term suitability for operation with hydrogen under the existing operating conditions in distribution networks (e.g., static loads and low exploitation of the strength thresholds).

Pipe steel grades that are recommended both in the DVGW Code of Practice G 463 “High-pressure gas pipelines made of steel pipes for a design pressure of more than 16 bar; planning and construction” (“Gashochdruckleitungen aus Stahlrohren für einen Auslegungsdruck von mehr als 16 bar; Planung und Errichtung”) for natural gas and in EIGA 121/14 for hydrogen, include L245, L290 and L360 (low-strength steels). These materials are predominantly used for renewals or network expansions in the distribution network area. According to the compendium “Hydrogen for gas distribution networks” (“Wasserstoff für Gasverteilnetze”) [16], no conventional steel is excluded from use for hydrogen in the existing distribution network.

Suitability of pipeline network materials in the distribution networks

Material	Suitabilit
Polyethylene 80 (PE 80)	✓
Polyethylene 100 (PE 100)	✓
Polyamide 11 (PA 11)	✓
Polyamide 12 (PA 12)	✓
Polyvinyl chloride (PVC)	✓
Polypropylene (PP)	✓
Polytetrafluorethylene (PTFE)	✓
Polyoxymethylene (POM)	✓
Aluminum alloys	✓
Copper/copper alloys	✓
Carbon steel (St 37/235, ASTM A106 grade B, API 5L grade B)	✓
Stainless steel (AISI 316 grades)	✓
Other steels (up to StE 210, 240, 290, 320, 360, 385, 415, 445, 480)	✓

Fig. 11: Current knowledge on the H_2 suitability of pipe materials (DVGW e.V., 2021)

Only in the case of a very small proportion of ductile iron pipes (1.5 percent) no final statement regarding H_2 suitability can be made at present. However, initial tests in the United Kingdom seem to indicate positive results.[17]

Grey cast iron pipes are unsuitable for hydrogen. However, these have been almost completely removed in the past through the nationwide grey cast iron replacement program.[18]

The proportion of pipeline materials reported as unknown is 2.4 percent. Current and future building works can be used to close the last gaps in the documentation. In the case of renewals or network expansions, H_2-ready pipeline materials are already being used by the distribution system operators.

Gas technology systems can be upgraded with a small additional investment

A total of 61,365 gas technology systems have been reported back by German gas distribution system operators in recent years via the DVGW G 410 portal [f]. These include systems for gas metering and controlling gas pressure.

Gas technology systems that are designed for the second gas family according to the DVGW code of practice G 260 cannot be operated with hydrogen with the current manufacturer recommendations without adjustments. Individual devices, especially gas measuring devices, are not approved for hydrogen and must be replaced.

The need to adapt a system is individual and is assessed by the responsible network operator. In this context, it must also be examined whether the former design parameters fit the future demand. If components with the current manufacturer's specifications are not sufficiently capable, they must be dimensioned larger.

In contrast to pipelines, gas technology systems can generally be replaced more quickly and with less planning and expense, partly because, unlike pipelines, they are easily accessible above ground. In addition, only a few gas technology systems for hydrogen require unscheduled modifications or replacement investments:

- Some of the systems are currently fed with biomethane or will be in the future and do not need to be adapted.
- The majority of the systems will be adapted as part of the regular modernization.
- The gas technology systems make up only a small part of the total investment costs of the asset groups.
- The manufacturers will adjust their recommendations, some of which are conservative, so that there is less need for H_2 renewal.

The DVGW's H_2 database and the GTP process will make a significant contribution to accelerating the transformation process in the coming years.

Network hydraulic aspects

Besides the issues of hydrogen suitability in terms of materials and function, network hydraulic aspects are also crucial in the context of network planning for the transformation and were taken into account in the development of the GTP.

Due to the low calorific value of hydrogen compared to natural gas (~1/3), the flow rate and the flow velocity increase threefold for the same amount of energy. The pressure loss increases by about 20 to 30 percent.

Following internal audits, distribution system operators of the H2vorOrt initiative confirmed that the gas networks constructed for natural gas can already transport hydrogen hydraulically in the network today, so that the specified pressure ranges are adhered to.

In the few networks where the defined pressure limits are breached, they can be readjusted without major technical effort (e.g., by increasing the pressure or sectioning the network).

Conclusion and outlook

From the research perspective, the transformation to 100 percent hydrogen is possible. This now needs to be transferred into operational practice. Since, on the basis of G 410, only 0.2 percent of the pipelines surveyed currently consist of secured, non-H_2-ready material, the pipelines of the distribution networks in Germany can basically be considered suitable for operation with 100 percent hydrogen in this first step.

During the following years of GTP development, these investigations will now be extended to further components and systems in order to determine the concrete need for upgrading for each grid operator and thus to plan the overall transformation ready for implementation.

At the same time, H_2-ready devices that are not the subject of the GTP should achieve an adequate market ramp-up and be used by end consumers in order to facilitate subsequent conversion processes.

[f] Not including house pressure regulators.

7 Conclusion, recommendations for action, and outlook

The planning process for the transformation of the German gas distribution grids to climate neutrality has commenced

The results presented in this report are planning statuses at the beginning of a multi-year, Germany-wide planning process. They clearly show the will and commitment of the distribution system operators to tackle the transformation of the grids swiftly and decisively. The fact that H_2 injection is already planned in large parts of Germany by 2030 speaks for itself and instils confidence that we will soon succeed in distributing large quantities of climate-neutral gaseous energy from imports as well as decentralized generation in Germany through an ambitious transformation of the gas supply infrastructure.

Following publication of the GTP planning guideline, 180 distribution system operators in Germany submitted a notification for the GTP planning process by 30 June 2022. However, as shown by the numerous requests we received for deadline extensions, many distribution system operators also failed to submit a 2022 submission within the set timeframe. Regardless of whether a company is among the 180 submitters this year or not, the underlying planning process with its dialogues and technical analyses has been initiated at a large number of German distribution system operators.

As is to be expected for the start of such a process, the participating distribution system operators have progressed in their planning to varying degrees. In part, intensive dialogue and concepts with the upstream grid operators already took place before the feedback was submitted, and in other cases these are still taking place or are imminent. However, the majority of the companies submitting feedback have already developed initial transformation paths for their network areas, which are now being adapted in an ongoing process based on the dialogue with the customers and local

The aim is for an investment-ready plan by 2025 at the latest

Planning will become more detailed in the 2023 GTP. More information from customers will be available and technical analyses will be expanded. Likewise, the hydrogen backbone of the transmission system operators is also expected to undergo a further iteration, which will also be based on the information gained from discussions in the GTP process. All this has an impact on the planning and helps to create a comprehensive target picture of the climate-neutral German gas infrastructure across all network levels. The goal is to have a coordinated Germany-wide plan ready for investment by 2025 at the latest.

The GTP implements the hydrogen strategy of the European distribution system operators via the European Ready4H_2 initiative, in which H2vorOrt represents Germany. Efforts are currently underway to establish country-specific concepts similar to the GTP in many other European countries. [19]

The GTP is a key component of the planning process laid out in the Hydrogen Report

In accordance with the German Energy Act (EnWG) §28q, operators of hydrogen networks and the TSOs were requested by the Federal Network Agency (BnetzA) to submit a joint report by 1 September 2022 on the current state of expansion of the hydrogen network and on the development of future network planning for hydrogen with the target year 2035.

Besides possible criteria for the consideration of hydrogen projects, this report particularly includes requirements for the determination of expansion measures.

For the development of a nationwide hydrogen infrastructure, however, all network levels are required, whereby each network in Germany has its own regional specifics that must be taken into account in order to achieve climate neutrality at the local level.

Accordingly, the implementation of hydrogen network planning in distribution networks on the basis of the GTP and the procedural handling between TSOs and DSOs were jointly described by the TSOs, numerous DSOs and the associations BDEW, DVGW, FNB Gas, VKU and the H2vorOrt initiative in the hydrogen report in accordance with §28q of the German Energy Act (EnWG).

The hydrogen report describes four levels in the transformation process:

1. With the creation of the GTP, the groundwork is laid at the DSO level to collect and report the prospective hydrogen requirements in a structured manner. This demand will be further substantiated through ongoing technical coordination discussions as part of the GTP process.
2. The basis for the planning of the conversion of pipelines to hydrogen by the TSOs are specific demand reports from the DSOs (made via a declaration of intent/MoU between TSOs and DSOs).
3. A final commitment is made by concluding a conversion schedule between TSO and DSO (encompasses a technical concept incl. conversion dates).
4. The TSO's line(s) will be converted to hydrogen.

What can you do to support the transformation?

What can you do to support the transformation?

Industrial customers

Talk to your local distribution system operator about hydrogen. Through this dialogue, you have the opportunity to jointly shape the transformation of your gas supply towards hydrogen. The distribution system operators are the bridge between the emerging German hydrogen backbone and you as a consumer. Through such joint dialogue it is possible to optimize the coordination of investment cycles and the provision of H_2 supply.

Municipalities

Engage in dialogue with your distribution system operator on municipal heat planning. The GTP provides a solid foundation for its development. Around half of all German households are supplied with gas today. The GTP takes this into account, as well as supra-regional supply interrelationships, process heat demand and, in particular, important infrastructure-related anchor customers (such as local industry). These interrelationships are of fundamental importance for municipal heating planning, as industrial energy demand, district heating supply and supra-regional interrelationships define a framework for infrastructure decisions in municipalities.

Network operators

Participate in the GTP. We recommend starting the basic process on the basis of the GTP Guide 2022 [20] in a timely manner and not waiting for the publication of the GTP Guide 2023. Create a basic plan, enter into dialogue with your customers and municipalities, coordinate with your upstream and downstream grid operators and start the technical analysis of your grids. We look forward to receiving your 2023 notification!

Politics

Recognition of costs

The German Energy Act 2021 (EnWG 2021) already calls for the joint financing of gas and hydrogen networks. [g] This should be implemented promptly in order not to hamper the transformation. In particular, it is necessary that the costs for establishing H_2-readiness in existing gas grids are recognized by the regulator as soon as possible. Since the recognition of the costs is a fundamental condition for the transformation of the grids, severe delays can become a stumbling block on the path to climate neutrality that endangers implementation.

In the last 15 years, distribution system operators have invested more than 32 billion euros in the expansion and renewal of the networks [21]. Today, this enables a cost-efficient and rapid upgrading of the infrastructure to hydrogen. The DVGW assumes total additional costs of 13 to 17 billion euros [22] for achieving H_2-readiness. [h, 23]

Scaling up volume

The ambitious continuation of the National Hydrogen Strategy (NHS) anchored in the coalition agreement must be embarked upon swiftly. The framework conditions have changed fundamentally, the demand for hydrogen will increase significantly and will have to be met much earlier. Germany is also striving to become the lead market for hydrogen technologies [i]. All this is also of fundamental importance for an ambitious transformation of the gas distribution networks. The National Hydrogen Council has set out the following concrete demands:

- Creation of a certification and trading system to establish a liquid hydrogen market
- Rapid development and expansion of the hydrogen infrastructure
- Swift ramp-up of the availability of climate-neutral hydrogen and its derivatives through domestic production and, in particular, through early imports from other European and non-European countries
- Creation of a coherent (funding) framework for the development of sales markets for hydrogen
- Research into and development of a sustainable hydrogen evolution with a focus on the realization of large-scale and holistic demonstration projects

Unbundling

The demands of the European Commission in the draft of the Gas Market Directive [24] for stricter unbundling must be resolutely opposed by the German government in the European Council. As the German Council of Federal States (Bundesrat) has already stated [25], this would significantly hinder the development of the hydrogen economy. In addition, the distribution system operators in Germany have proven that the implementation of the unbundling rules for gas, which have been in place since 2009, have enabled competition that is unique in Europe. The joint operation of gas and hydrogen pipelines allows for a very flexible on-site approach tailored to customers and municipalities.

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[g] German Energy Industry Act §112 (1): “The Federal Ministry for Economic Affairs and Energy shall publish a concept for the further development of the German hydrogen grid by 31 December 2022. In the light of developing Union legal foundations – against the backdrop of the objective of adapting the regulatory framework for the joint regulation and financing of the gas and hydrogen grids - the concept shall include considerations on a transformation from gas grids to hydrogen grids, including step-by-step integrated system planning.”

[h] In comparison, the annual Renewable Energy Sources Act (EEG) injection tariff has amounted to 10 to 15 billion euros per year over the last 10 years. [14]

[i] Coalition agreement 2021: “Thus, we seek to become the lead market for hydrogen technologies by 2030 and develop an ambitious update of the National Hydrogen Strategy for this purpose.”

8 Appendices

APPENDIX A: PLANNING ASSUMPTIONS

The premises for the preparation of the GTP from the GTP Guidelines 2022 are given below. The plans were prepared by the individual companies according to these premises based on the local conditions. These plans were then aggregated and evaluated for this report.

Further developments of the legal framework will be taken into account in the planning premises of subsequent GTP guidelines.

I. I.Market framework conditions

a) It is assumed that policy will create the framework conditions that facilitate the progressive decarbonization of gas consumption – reflecting the federal government's climate objectives. This is in line with the call of H2vorOrt to have a green gas target, along with an implementation pathway like for example, a rising quota system.
b) The GTP assumes that H_2-readiness measures will soon be recognized under the gas network regulation.
c) Climate objectives are decisive for transformation planning, not current theories on quantity provision of climate-neutral gases. To be able to realize this reduction potential, the necessary quantities of climate-neutral gases must be made available. We assume that the network development plan will fully ensure a timely and demand-oriented expansion of supply infrastructure for climate-neutral gases, a significant portion of which will be generated in a decentralized way. We trust that policymakers will create the framework conditions needed for a corresponding market ramp-up in terms of production.

II.Technical framework conditions

a) The entire distribution network should be able to transport climate-neutral gases by 2040 at the latest. Networks for the long-term transport of 100 Vol-100% H_2 must therefore be 100% H_2 ready by 2040 at the latest.
b) The variety of climate-neutral gases (hydrogen, biomethane, SNG, etc.) should be optimally exploited in line with targets. Guaranteed decentralized generation should be incorporated.
c) Irrespective of scheduling, maintenance activities will already be carried out within the scope of H_2-readiness.
d) The DVGW will ensure that the rules on 20 Vol.-%/ 100% H_2 are in place in a timely fashion.
e) Current political will indicates that new CHP plants or gas power plants must be built to be H_2 ready. It is recommended that this requirement be applied as broadly as possible, also to new RLM customers/ applications or that existing customers are informed sufficiently early about the necessity of H_2-readiness.

III. Climate policy framework conditions

a) Regional climate objectives and requirements are the target parameters (municipal heat planning). The GTP functions here as a bridge to convey the climate protection requirements of the municipalities to the TSOs as well as to the federal state and national political levels. Achieving sectoral targets will be supported at the municipal level (bottom-up analyses of the local authorities).
b) In the dialogue on municipal heat planning, which is to be introduced nationwide according to the coalition agreement, it should be noted that the (already existing) assets in gas infrastructures could be usefully complemented by heating networks to facilitate an optimal macroeconomic solution for the accelerated, heating transformation on the local level.
c) The consolidated conversion plan across all DSOs must add up to fulfil the German climate target (Climate Change Act). Spatial and temporal development plans will be accounted for overall in line with the target.
   - 65 % less CO_2 compared to 1990 by 2030
   - 88 % less CO_2 compared to 1990 by 2040
   - Climate neutrality by 2045

IV. Other framework conditions

a) The GTP will be oriented towards a quantity structure that guarantees maintaining the current security of supply in various future demand scenarios.

b) The GTP will be updated annually by every distribution system operator.

c) The GTP is the basis for a subsequent conversion by sub-networks to H_2 and other climate neutral gases, similar to the H-gas/ L-gas conversion. It is assumed that the federal government will create a similar legal framework in time for this purpose (§19a EnWG).

APPENDIX B: PARTICIPATING COMPANIES

The following companies submitted feedback for the GTP 2022:

- Alliander Netz Heinsberg GmbH
- Avacon Hochdrucknetz GmbH
- AVU Netz GmbH
- Bayernwerk Netz GmbH
- bnNetze GmbH
- Braunschweiger Netz GmbH
- Celle-Uelzen Netz GmbH
- Creos Deutschland GmbH
- EAM Netz GmbH
- ELE Verteilnetz GmbH
- ENA Energienetze Apolda GmbH
- Energie- und Wasserwerke Bautzen GmbH
- Energie Waldeck-Frankenberg GmbH
- Energienetze Bayern GmbH & Co. KG
- Energienetze Offenbach GmbH
- ENERGIERIED GmbH & Co. KG
- Energieversorgung Lohr-Karlstadt und Umgebung GmbH & Co. KG
- Energieversorgung Ergolding-Essenbach GmbH
- Energieversorgung Halle Netz GmbH
- Energieversorgung Schwarze Elster GmbH
- energis-Netzgesellschaft mbH
- ENERVIE Vernetzt GmbH
- e-netz Südhessen AG
- ENNI Energie & Umwelt Niederrhein GmbH
- Erdgas Burgbernheim GmbH
- Erdgas Mittelsachsen GmbH
- Erdgasversorgung Erding GmbH & Co.KG
- ESTW Erlanger Stadtwerke AG
- ESWE Versorgungs AG
- EVB-Netze GmbH
- EW Eichsfeldgas GmbH
- EWE NETZ GmbH
- EWR Netz GmbH
- FairNetz GmbH
- Feuchter Gemeindewerke GmbH
- Freiberger Erdgas GmbH
- Gas und Wärme GmbH Bad Aibling
- Gasnetz Hamburg GmbH
- Gasversorgung Dingolfing GmbH & Co. KG
- Gasversorgung Eisenhüttenstadt GmbH
- Gasversorgung Pfaffenhofen GmbH & Co. KG
- Gelsenwasser Energienetze GmbH
- Gemeindewerke Garmisch-Partenkirchen
- Gemeindewerke Kirkel GmbH
- Gemeindewerke Schwarzenbruck GmbH
- Gemeindewerke Wendelstein Gasversorgung GmbH
- GeraNetz GmbH
- Gewerbepark Nürnberg-Feucht GmbH
- GWB-Netz GmbH
- Heilbronner Versorgungs GmbH
- Herzo Werke GmbH
- HEWA GmbH
- inetz GmbH
- INNergie GmbH
- KEW Kommunale Energie- und Wasserversorgung AG
- Kommunale Energienetze Inn-Salzach GmbH & Co. KG
- Leitungspartner GmbH
- LSW Netz GmbH & Co.KG
- Mainfranken Netze GmbH
- Main-Kinzig Netzdienste GmbH
- medl GmbH
- Meißener Stadtwerke GmbH
- Mitteldeutsche Netzgesellschaft Gas mbH
- MVV Netze GmbH
- N-ERGIE Netz GmbH
- Netz Leipzig GmbH
- Netze BW GmbH
- Netze ODR GmbH
- Netze-Gesellschaft Südwest mbH
- Netzgesellschaft Frankfurt (Oder)
- Netzgesellschaft Gütersloh mbH
- Netzgesellschaft Köthen mbH
- NETZGESELLSCHAFT NIEDERRHEIN MBH
- Netzwerke Saarlouis GmbH
- NEW Netz GmbH
- NRM Netzdienste Rhein-Main GmbH
- Oberhessengas Netz
- OsthessenNetz GmbH
- Pfalzgas GmbH
- Regionalwerk Bodensee Netze GmbH & Co. KG
- Regionetz GmbH
- Rheinische NETZGesellschaft mbH
- RhönEnergie Osthessen GmbH
- SachsenNetze GmbH
- schwaben netz regional gmbh
- Siegener Versorgungsbetriebe GmbH
- Städtische Werke Magdeburg GmbH & Co. KG
- Stadtnetze Münster GmbH
- Stadtwerke Schwabach GmbH

- Stadtwerk am See GmbH & Co. KG
- Stadtwerk Tauberfranken GmbH
- Stadtwerke Ahaus GmbH
- Stadtwerke Ansbach GmbH
- Stadtwerke Bad Reichenhall KU
- Stadtwerke Bad Salzuflen GmbH
- Stadtwerke Bad Saulgau
- Stadtwerke Bad Windsheim
- Stadtwerke Bad Wörishofen
- Stadtwerke Bernau GmbH
- Stadtwerke Bernburg Gasnetz GmbH
- Stadtwerke Bochum Netz GmbH
- Stadtwerke Böhmetal GmbH
- Stadtwerke Burg Energienetze GmbH
- Stadtwerke Dillingen/Saar Netzgesellschaft mbH
- Stadtwerke Dinkelsbühl
- Stadtwerke Eichstätt Versorgungs-GmbH
- Stadtwerke Elbtal GmbH
- Stadtwerke Elmshorn
- Stadtwerke Erdgas Plauen GmbH
- Stadtwerke Essen AG
- Stadtwerke Feuchtwangen
- Stadtwerke Friedberg
- Stadtwerke Georgsmarienhütte Netz GmbH
- Stadtwerke GmbH Bad Kreuznach
- Stadtwerke Gotha NETZ GmbH
- Stadtwerke Herford GmbH
- Stadtwerke Ilmenau GmbH
- Stadtwerke Jena Netze GmbH
- Stadtwerke Karlsruhe Netzservice GmbH
- Stadtwerke Königslutter GmbH
- Stadtwerke Konstanz GmbH
- Stadtwerke Kulmbach
- Stadtwerke Langen GmbH
- Stadtwerke Lehrte GmbH
- Stadtwerke Lindau (B) GmbH & Co. KG
- Stadtwerke Löbau GmbH
- Stadtwerke Münchberg
- Stadtwerke Neuburg a. d. Donau Gas
- Stadtwerke Neumarkt i.d.Opf. Energie GmbH
- Stadtwerke Neustadt an der Aisch GmbH
- Stadtwerke Nienburg / Weser GmbH
- Stadtwerke Ochtrup
- Stadtwerke Passau GmbH
- Stadtwerke Pirmasens Versorgungs GmbH
- Stadtwerke Radolfzell GmbH
- Stadtwerke Rees GmbH
- Stadtwerke Reichenbach Vogtland GmbH
- Stadtwerke Riesa GmbH
- Stadtwerke Rosenheim Netze GmbH
- Stadtwerke Roth
- Stadtwerke Röthenbach a.d. Pegnitz GmbH
- Stadtwerke Saarbrücken Netz AG
- Stadtwerke Schüttorf · Emsbüren GmbH
- Stadtwerke Sindelfingen GmbH
- Stadtwerke Speyer GmbH
- Stadtwerke Stein GmbH & Co. KG
- Stadtwerke Straubing Strom und Gas GmbH
- Stadtwerke Sulzbach/Saar GmbH
- Stadtwerke Treuchtlingen
- Stadtwerke Velbert GmbH
- Stadtwerke Waren GmbH
- Stadtwerke Weißenburg GmbH
- Stadtwerke Wertheim GmbH
- Stadtwerke Winsen (Luhe) GmbH
- Stadtwerke Wolfenbüttel GmbH
- Stadtwerke wunstorf GmbH & CO. KG
- Stadtwerke Zeven GmbH
- Stadtwerke Zirndorf GmbH
- Stadtwerke Zittau GmbH
- StWL Städtische Werke Lauf a.d. Pegnitz GmbH
- SÜC Energie und H2O GmbH
- SVS-Versorgungbetriebe GmbH
- swa Netze GmbH
- SWE Netz GmbH
- SWM Infrastruktur GmbH & Co. KG
- SWO Netz GmbH
- SWP Stadtwerke Pforzheim GmbH & Co.KG
- SWTE Netz GmbH & Co. KG
- Syna GmbH
- Tegernseer Erdgasversorgungsgesellschaft mbH & Co. KG
- TEN Thüringer Energienetze GmbH & CO. KG
- Teutoburger Energie Netzwerk
- TWS Netz GmbH
- WerraEnergie GmbH
- wesernetz Bremen
- wesernetz Bremerhaven
- Westnetz GmbH
- WSW Netz GmbH
- ZVO Energie GmbH
- Zweckverband Gaswerk Illingen

The following companies have announced their intention to submit feedback from 2023 onwards:

- E.DIS Netz GmbH
- ElbEnergie GmbH
- enercity Netz GmbH
- Energienetze Mittelrhein GmbH & Co. KG
- HanseGas GmbH
- NBB Netzgesellschaft Berlin-Brandenburg mbH & Co. KG
- Netzgesellschaft Düsseldorf mbH
- Schleswig-Holstein Netz AG
- Stadtwerke Heidelberg Netze GmbH
- Stadtwerke Traunstein GmbH & Co. KG

List of abbreviations

Abbreviation	Description
ASME	American Society of Mechanical Engineers
BDEW	Bundesverband der Energie- und Wasserwirtschaft e.V. (German Association of Energy and Water Industries)
BNetzA	Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen (Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railways)
CHP	Combined heat and power plant
DSO	Distribution system operator
DVGW	Deutscher Verein des Gas- und Wasserfaches e.V. (German Technical and Scientific Association for Gas and Water)
EEG	Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act)
IGA	European Industrial Gases Association
EnWG	Energiewirtschaftsgesetz (German Energy Industry Act)
ETS	European Union Emissions Trading System
GaWaS	Gas-water statistics of the DVGW (G 410)
GTP	Gas network area transformation plan
HCL	Household connection line
MoU	Memorandum of Understanding
NDP	Network development plan
NUTS-3	Administrative level of rural and urban districts
NHS	National Hydrogen Strategy
PA	Polyamide
PE	Polyethylene
PVC	Polyvinyl chloride
RLM	Customers with consumption metering (registrierende Leistungsmessung (RLM)) are major customers with a consumption of 1.5 million kWh per year, such as industrial companies or large commercial enterprises.
SL	Supply line
SLP	Standard Load Profile
SNG	Synthetic Natural Gas
StE	Alloy steel
TSO	Transmission system operator
VKU	Verband kommunaler Unternehmen e.V. (German Association of Local Public Utilities of municipally determined infrastructure undertakings and economic enterprises)

List of references

[0] https://www.umweltbundesamt.de/daten/energie/primaerenergieverbrauch#primarenergieverbrauch-nach-energietragern; Accessed 02.09.2022.

[1] AG Energiebilanzen e.V. (2021).

[2] Federal Network Agency, Federal Cartel Office (2022): Monitoring report 2021, p. 344.

[3] DVGW-Merkblatt G 221: Leitfaden zur Anwendung des DVGW-Regelwerks auf die leitungsgebundene Versorgung der Allgemeinheit mit wasserstoffhaltigen Gasen und Wasserstoff.

[4] Kemmler, Andreas (2020): Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050, Prognos AG; Buttermann, Hans Georg (2021): Energieverbrauch in Deutschland im Jahr 2020, AG Energiebilanzen e. V.

[5] Bundesnetzagentur, Bundeskartellamt (2022): Monitoringbericht 2021, S. 344.

[6] Bundesnetzagentur, Bundeskartellamt (2022): Monitoringbericht 2021, S. 346.

[7] AEE (2017): RENEWS KOMPAKT Nr. 38 (https://www.unendlich-viel-energie.de/mediathek/publikationen/erneuerbare-energie-fuer-die-industrie-prozesswaerme-aus-bioenergie-sorgt-fuer-unabhaengigkeit-und-klimaschutz; abgerufen am: 29.08.2022).

[8] Fraunhofer IEE / Fraunhofer ISE (2022): Erste Ableitungen aus der „Bottom-Up-Studie zu Pfadoptionen einer effizienten und sozialverträglichen Dekarbonisierung des Wärmesektors“ mit Blick auf die Kommunale Wärmeplanung und die Rolle von Wasserstoff (https://www.wasserstoffrat.de/fileadmin/wasserstoffrat/media/Dokumente/2022/2022-06-30_NWR-Waermestudie_Zwischenergebnisse_FhG.pdf; abgerufen am: 29.08.2022).

[9] FNB Gas (2022): Bericht zum aktuellen Ausbaustand des Wasserstoffnetzes und zur Entwicklung einer zukünftigen Netzplanung Wasserstoff.

[10] Fachverband Biogas (2021): Branchenzahlen 2020 und Prognose der Branchenentwicklung 2021.

[11] DVGW (2019): Erweiterte Potenzialstudie zur nachhaltigen Einspeisung von Biomethan unter Berücksichtigung von Power-to- Gas und Clusterung von Biogasanlagen; DVGW (2019): Ermittlung des Gesamtpotentials erneuerbarer Gase zur Einspeisung ins deutsche Erdgasnetz; Wasserstoffleitprojekt TransHyDE / Fraunhofer- Einrichtung für Energieinfrastrukturen und Geothermie IEG / Max- Planck-Institut für Chemische Energiekonversion / cruh21 GmbH (2022): Hintergrundpapier zu Gasinfrastrukturen im Lichte des russischen Angriffskriegs auf die Ukraine.

[12] H2vorOrt (2022): Die Auswirkungen des EU-Gaspakets auf die deutsche Energiewende (https://www.h2vorort.de/fileadmin/Redaktion/PDF/h2vorort-auswirkungen-eu-gaspaket-wasserstoff.pdf; Accessed: 29.08.2022).

[13] DVGW (2022): Roadmap Gas 2050. Transformationspfade der deutschen Gasinfrastruktur inkl. Gasanwender (https://www.dvgw.de/medien/dvgw/forschung/berichte/g201824-rmg2050-d2.3-transformationspfade.pdf; Accessed: 29.08.2022).

[14] Statista: Höhe der Einspeisevergütung für Strom nach dem EEG in Deutschland in den Jahren 2000 bis 2021 (https://de.statista.com/statistik/daten/studie/36306/umfrage/entwicklung-der-verguetung-nach-dem-eeg-seit-2000; Accessed: 29.08.2022).

[15] Bundesnetzagentur, Bundeskartellamt (2022): Monitoringbericht 2021, p. 344.

[16] DBI (2021): Kompendium Wasserstoff in Gasverteilnetzen (https://www.dbi-gruppe.de/h2-kompendium-vnb.html; Accessed: 23.08.2022).

[17] HyDeploy (2021): HyDeploy2 Project. Gas Network Innovation Competition/Cadent. 3rd Project Progress Report (https://hydeploy.co.uk/app/uploads/2022/06/HYDEPLOY2-THIRD-OFGEM-PPR.pdf, Accessed: 29.08.2022), p. 6.

[18] DVGW (2020): Methan-Emissionen der Erdgas-Infrastruktur (https://www.dvgw.de/medien/dvgw/leistungen/publikationen/methanemissionen-erdgas-zahlen-fakten-dvgw.pdf, Accessed 29.08.2022), p. 12.

[19] Ready4H2 (2022): A roadmap for local gas distribution networks to become the leading hydrogen distribution infrastructure in 2045.

[20] Available online on the H2vorOrt website (https://www. h2vorort.de/publikationen/gtp).

[21] According to Federal Network Agency monitoring reports 2007-2021.

[22] DVGW (2022): Roadmap Gas 2050. Transformationspfade der deutschen Gasinfrastruktur inkl. Gasanwender (https://www.dvgw.de/medien/dvgw/forschung/berichte/g201824-rmg2050-d2.3-transformationspfade

[23] Statista: Höhe der Einspeisevergütung für Strom nach dem EEG in Deutschland in den Jahren 2000 bis 2021 (https://de.statista.com/statistik/daten/studie/36306/umfrage/entwicklung-der-verguetung-nach-dem-eeg-seit-2000; Accessed: 29.08.2022).

[24] Europäische Kommission (15.12.2021): Proposal for a Directive of the European Parliament and of the Council concerning common rules for the internal markets in renewable gases and natural gas and hydrogen.

[25] Bundesrat (8.4.2022): Document 56/22 (resolution).

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