Draft of the joint application for the hydrogen core network

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Contents

Figures and tables

1 Introduction and background

The gas transmission system operators share the German government's goal of a rapid and cost-efficient development of the hydrogen infrastructure that enables the market ramp-up and is embedded in the EU internal market.

With its initiative to amend the Energy Industry Act (EnWG), the German government has laid the essential regulatory, antitrust and network planning foundations required for the development of an expandable hydrogen core network. As this draft for the joint application of the gas transmission system operators for the hydrogen core network is presented, the draft law is still in the legislative process, which is expected to be completed in late autumn 2023.

With this draft application, the transmission system operators, in consultation with the Federal Ministry for Economic Affairs and Climate Action (BMWK), are responding to the request from the Federal Network Agency (BNetzA) to allow the approving authority to carry out an initial review and consultation with the market and the public at an early stage. After the amendment to the EnWG comes into force, the transmission system operators will submit a final joint application for the establishment of a hydrogen core network to the BNetzA in accordance with Section 28r (2) of the draft amendment to the EnWG[1] [German Bundestag, 2023], subject to the legal regulations still to be adopted, in particular the legally secure anchoring of a financing concept suitable for the capital market and the approval of the respective supervisory bodies of the transmission system operators. This final application will also be reviewed by the authority. Once the application has been confirmed by the BNetzA, the grid operators will immediately begin implementing the hydrogen core network.

A Germany-wide hydrogen core network that enables broad access to hydrogen as an energy carrier or as a raw material forms the basis for the development of a liquid hydrogen market and is a prerequisite for Germany to be able to fulfil its desired pioneering role in climate protection. To this end, it is important to plan the hydrogen core network in a forward-looking and scalable manner.

The regulations in the draft bill of the EnWG amendment [German Bundestag, 2023] represent a clear mandate for transmission system operators to develop a supra-regional hydrogen core network (onshore and offshore). Other infrastructures that are suitable for safely transporting hydrogen at the transmission level are to be taken into account.

Existing requirements at the distribution network level that meet the criteria of the scenario for the hydrogen core network are already being taken into account in terms of capacity in the technical planning for the hydrogen core network. Additional requirements are to be included in a second step as part of the planned control process for integrated network development planning (hydrogen and methane). The transmission system operators had already submitted corresponding proposals in this regard in September 2022 with the publication of the hydrogen report in accordance with Section 28p EnWG, which were developed together with the distribution system operators, among others. In addition, further amendments to the EnWG are necessary, for example to define the link to the electricity network development plan, but also to establish an upstream energy

[1] EnWG-E refers to the amendment of the cabinet resolution of May 24, 2023, which forms part of the amendment to the EnWG already initiated by cabinet resolution of November 15, 2023, whereby Section 28r becomes Section 28q.

scenario process that creates a common basis for the electricity and gas (hydrogen and methane) network development plans. The Federal Cabinet launched a corresponding legislative initiative on November 15, 2023. In addition, the legal and regulatory requirements for the conversion to hydrogen of network areas and connected customers at the distribution level must be created soon.

With this draft application, the transmission system operators are submitting their plans for the hydrogen core network, including suitable pipelines from other potential hydrogen network operators who responded to the opportunity to comment in July 2023.

The transmission system operators examined the pipelines reported by these other potential hydrogen network operators on the basis of technical and legal criteria. The reported infrastructure had to be able to contribute to meeting the objectives set out in law and meet the criteria for the hydrogen core network scenario. Where pipeline notifications met the technical and legal requirements for integration into the hydrogen core network and the infrastructure is required to fulfil the transmission task, they were taken into account for the modelling exercise and became part of the hydrogen core network. This was done regardless of the fact that some potential hydrogen network operators made the use of their pipeline notification subject to clarification of the regulatory and financial conditions for the hydrogen core network.

In the interests of overall economically optimized planning, the hydrogen core network will consist primarily of pipelines converted from the existing natural gas infrastructure as well as new hydrogen pipelines to be built. For the natural gas pipelines to be converted, the transmission system operators will demonstrate that, at the time such pipelines are converted to hydrogen, they have ensured that the remaining transmission system can meet the capacity requirements on which the supplemented scenario framework for the Gas Network Development Plan 2022-2032 is based. To this end, the transmission system operators have identified the necessary additional expansion measures for the natural gas network, which must be approved at the same time as the hydrogen core network.

The transmission system operators point out that, as the draft application is being published, there are still numerous unanswered questions, and not only in relation to the financing of the hydrogen core network (e.g. the access and ramp-up fee regulation regime). There are also major uncertainties regarding a market model for hydrogen, including the marketing of transmission capacities, or there are no regulations in place. For example, future market roles of storage facilities, especially in the market ramp-up phase, have not yet been clarified.

2 Scenario for the hydrogen core network

The following outlines the basic procedure for determining the scenario for the hydrogen core network in 2032 (see section 2.1) and the resulting findings (see section 2.2).

2.1 Basic procedure for determining the scenario for the hydrogen core network

Criteria for defining the scenario for the hydrogen core network

The legal basis for the hydrogen core network scenario is set out in Section 28r EnWG-E (the draft Energy Industry Act). For operationalization, the criteria for defining the scenario for the hydrogen core network were further specified and agreed in joint discussions between BMWK, BNetzA, BKAmt, BMF, FNB Gas and BDEW. The scenario has a controlling function for the hydrogen core network and is the basis for hydrogen core network modelling by the transmission system operators.

The starting point for the hydrogen core network scenario was the result of the Hydrogen Production and Demand - HPD *("Wasserstoff Erzeugung und Bedarf – WEB"*) market survey from the Gas Network Development Plan 2022-2032 [FNB Gas, 2023], which was adjusted using the latest information. For example, projects that are no longer being pursued, as far as the transmission system operators are aware, were removed. Analyses of the hydrogen strategies of the federal states and feedback on specific projects from the federal states were also incorporated into the scenario.

The next step was for the transmission system operators to review the project notifications to determine if they meet the following BMWK and BNetzA criteria. The selection of projects for the feed-in and withdrawal of hydrogen based on these criteria is intended to ensure that the hydrogen core network to be determined meets the political targets.

The scenario for the hydrogen core network is based on the following criteria:

- The project is part of an IPCEI or PCI process.
- The project serves to integrate the hydrogen core network into a (prospective) European hydrogen network.
- The project is part of a real-world laboratory for the energy transition, which is funded by the BMWK.
- The project serves to decarbonize the following industrial sectors and processes:
  - Iron and steel:
    - Production of crude steel from primary route
    - Heating and annealing furnaces, steel rolling mills: continuous heating of flat/long steel, dis/continuous heat treatment of flat steel

    - Forming technology: dis/continuous heating of forged components
  - Chemicals:
    - Ammonia synthesis
    - Basic chemical production: ethylene/olefins, methanol
  - Refineries:
    - Desulphurization, hydrocracking, e-kerosene, methanol
  - Glass industry, incl. glass fibre:
    - Continuous melting of container glass in large systems
    - Continuous melting of flat glass
  - Medium to large production facilities for ceramics and brick products
- The project serves to feed in hydrogen produced by electrolysis plants. The planned entry capacities for hydrogen are scaled down generally to 50% per site. Deviating from this, the full planned entry capacity (i.e. 100%) is used as the basis for the following electrolysers:
  - Electrolysers promoted as IPCEI (approx. 2.5 GW_e)
  - Electrolysers that are being promoted as real laboratories for the energy transition (approx. 0.2 GW_e)
  - Conveyed offshore electrolysers (approx. 1 GW_e brought onshore via AquaDuctus pipeline)
- The project serves to store hydrogen and has been pre-notified as an IPCEI project or has concrete indications of investment.
- Consideration of CHP power plant locations from the market master data register with an electrical CHP capacity of more than 100 MW (corresponds to a rated heat input of at least 235 MW_{th}).

Based on these criteria and taking into account a regional balance, projects were included in the scenario for the hydrogen core network and are therefore included in the modelling. Demand indications that have not been included in the scenario can potentially be included in the planned rolling process for integrated network planning (hydrogen and methane) that will follow shortly afterwards.

An overview of the projects included in the scenario for the hydrogen core network can be found in Annex 1 to the draft joint application for the hydrogen core network.

Explanation of the criteria for defining the scenario for the hydrogen core network

The criteria agreed between the BMWK, BNetzA, BKAmt, BMF, FNB Gas and BDEW for determining the scenario for the hydrogen core network are explained in more detail below.

IPCEI projects (Important Projects of Common European Interest) and **PCI projects** (Projects of Common Interest) as well as the **integration into a European hydrogen network** form the basis for the consideration of infrastructures in the hydrogen core network.

The **Important Projects of Common European Interest** (IPCEI) are large-scale hydrogen projects that are to receive state funding as part of a joint European hydrogen project (so-called hydrogen IPCEI) (co-financing: federal government 70%, federal state 30%). The projects were selected as part of an expression of interest procedure, taking special requirements into account. The German projects will be funded together with projects in European partner countries. The various national projects are to be interconnected in such a way that all countries benefit from each other and can develop a European hydrogen economy together. The hydrogen core network takes into account the production, consumption, pipeline and storage projects of the hydrogen IPCEI.

Projects of common interest (PCI/PMI) are cross-border infrastructure projects that connect the energy systems of EU Member States (and possibly beyond). The EU Commission awards PCI status for cross-border infrastructure projects every two years. With this status, project developers can apply for further (EU) funding, e.g. from the Connecting Europe Facility (CEF). In addition, PCIs should benefit from improved regulatory conditions, lower administrative costs thanks to optimized environmental assessment procedures as well as accelerated planning and approval processes – especially at national level. By mid-December 2022, project developers (mostly European transmission system operators) had submitted a total of 180 applications for PCI/PMI status. Many of the projects combine several individual projects as an interconnection/corridor. The majority of the projects are geared towards hydrogen supply in Germany, among other things. Divided into three regional groups, in which Germany is represented, the projects and their contribution to the criteria of market integration, security of supply and competition are discussed. The EU Commission is to adopt the delegated act to draw up the first Union list containing hydrogen projects by November 30, 2023, in accordance with Regulation (EU) 2022/869 Article 3 (4).

The prospective **integration of the hydrogen core network into a European hydrogen network** is in line with the German government's National Hydrogen Strategy (NHS). The aim is to establish stronger and closer cooperation with interested EU member states in the medium term, which will enable a coordinated market ramp-up, set common standards, facilitate coordination and enable coordinated imports. A large proportion of the hydrogen required in Germany will be covered by imports.According to the Federal Government's assessment based on an analysis of current scenarios, around 50 % to 70 % of hydrogen demand will be covered by imports from abroad in the long term.

Real-world laboratories for the energy transition on hydrogen technologies will also be included in the hydrogen core network. These projects, which are funded by the BMWK and others, make it possible to test hydrogen technologies in practical applications under real conditions and on an industrial scale, which is facilitated by a connection to the hydrogen core network.

In the **industrial sector,** hydrogen-based technologies are a suitable transformation option, especially in those sectors where they replace fossil raw materials such as natural gas, oil or coal in material use. Likewise, the energetic use of hydrogen can also be the only option for decarbonization in certain areas. For this reason, projects from the project list of the transmission system operators ["Gas Network Development Plan 2022-2032", FNB Gas, 2023] determined as part of a market survey on hydrogen production and demand are included in the modelling of the hydrogen core network. These are then assigned to industrial sectors where, from today's perspective, there is no useful option for decarbonizing the industrial process as an alternative to hydrogen use. This includes iron and steel, chemicals, refineries, the glass industry, ceramics and brick products.

According to the BMWK's long-term scenarios, **hydrogen storage** in Germany will play a decisive role in the success of the energy transition in the future. Due to the advantageous geological conditions in Germany (salt domes), it also makes sense to implement extensive storage projects for hydrogen with a view to the European dimension. In the future, hydrogen storage facilities will be of central importance for supplying hydrogen to hydrogen-fired power plants and combined heat and power plants, among other things. By connecting storage sites and building a cross-border gas transmission infrastructure, German storage facilities can also facilitate cross-border trade in hydrogen, which promotes the integration of the European hydrogen market. Investment in the German hydrogen storage infrastructure can improve the overall security of supply for hydrogen within the EU.

The hydrogen core network should furthermore guarantee sufficient connection options for **production regions and electrolysers.** The feed-in capacity of electrolysers to be taken into account should be in line with the National Hydrogen Strategy. In the current version, a target value of at least 10 GW (domestic electrolysis) is specified for the year 2030 and a strong ramp-up is targeted for the following years. In order to implement the targets and assumptions of the National Hydrogen Strategy in practice, the projects identified by the transmission system operators as part of a market survey on hydrogen production and demand in 2021 will be included with adjusted capacity for the modelling of the hydrogen core network. The locations of electrolysers are to be selected in a system-friendly manner in order to ensure compatibility with national hydrogen and electricity network planning and also to guarantee secure electricity network operation in the future. This is because only electrolysers in close proximity to the renewable energy plants can draw electricity without bottlenecks at all times of the year. Locations that serve the system thus avoid bottlenecks in the transmission network, additional network expansion and additional CO_2 emissions from redispatch power plants.

The hydrogen core network is also intended to cover large **combined heat and power** (CHP) sites for which continued operation with the subsequent use of hydrogen is likely. The threshold value of 100 megawatts of electrical CHP capacity focuses on locations with high heat demand, where it is highly likely that CHP will continue to play a role in heat supply in the future. Initial preliminary considerations based on this size criterion have also indicated good spatial coverage by the hydrogen core network. While the size criterion is aimed at the spatial design of the starter network, the additional assumption of an average of 2,500 full utilization hours is relevant for the dimensioning of the network and the amount of hydrogen to be provided. An average operating time of 2,500 full load hours per year should be assumed for each megawatt of electrical CHP capacity. In a first step, the modelling is based on the assumption that the majority of existing power plant sites will be converted to hydrogen use at a later date. This is to be expected particularly for locations with high heat demand. A survey of transmission system operators was also used to take into account locations for which there are already sufficiently solid plans at the present time (June 2023) for a later conversion to hydrogen operation.

The **regional balance** of the hydrogen core network is an important concern for the German government. The hydrogen core network includes projects of a supra-regional nature to create a Germany-wide hydrogen network. The route of the hydrogen core network therefore includes both north-south and west-east corridors in order to connect central hydrogen locations throughout Germany.

The results of the scenario for the hydrogen core network are presented below.

2.2 Results of the scenario for the hydrogen core network

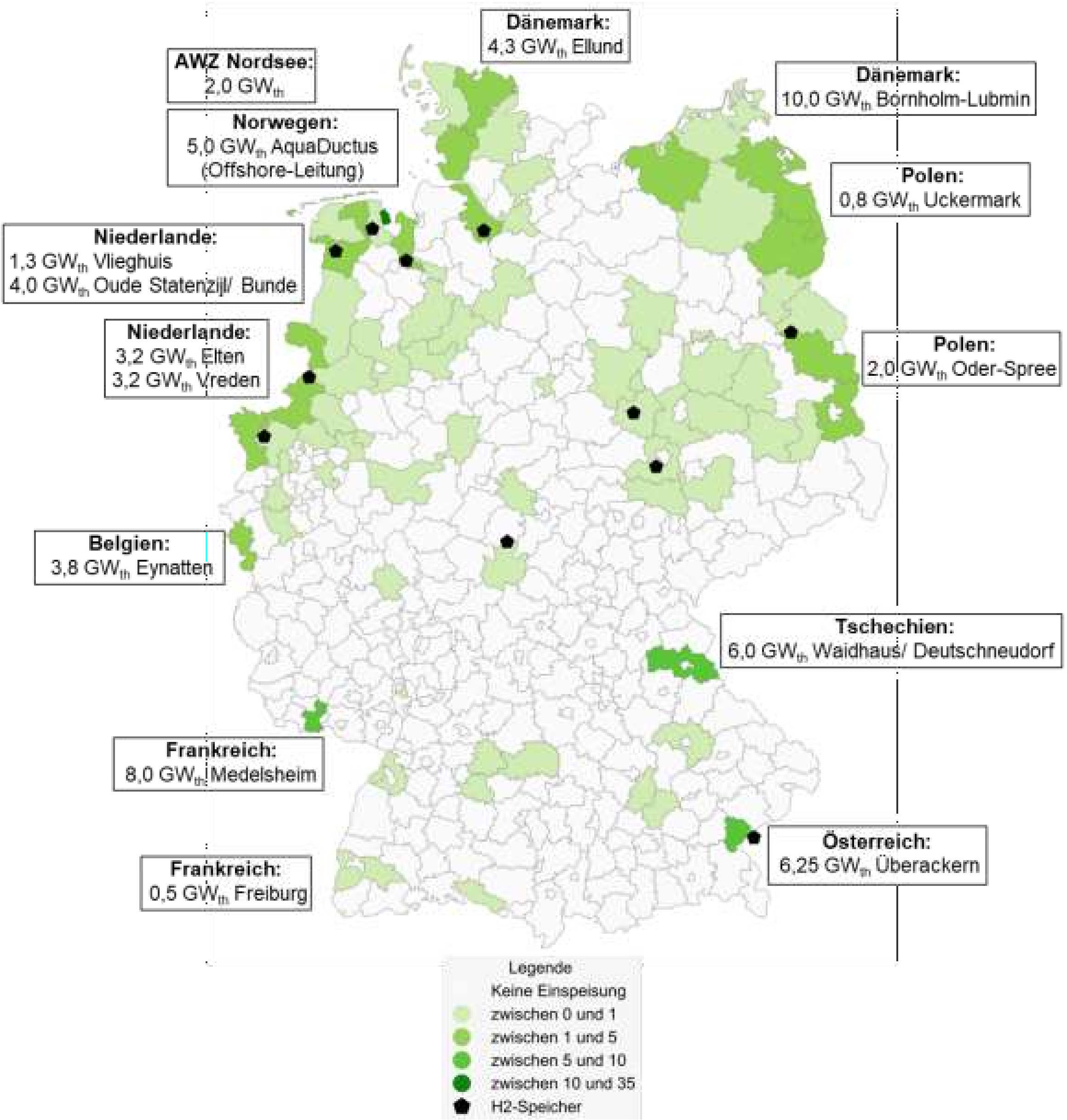
A total of 309 hydrogen projects have been considered in the scenario for the hydrogen core network. Table 1 below shows the calculated entry capacities for hydrogen in total, and Figure 1 shows them for every region at district level. Other entries include, in particular, imports via marine terminals where hydrogen is landed in another form, such as LOHC or ammonia, and then fed in as hydrogen.

Table 1: Entry capacities according to criteria, data for 2032 based on calorific value

	Unit	Cross-border IP	Electrolysis	Storage	Other feeds	Total
Feed-in power	GW_{th}	58	15	8	19	101

Source: Transmission system operators

Figure 1: Entry capacities for hydrogen at district level and at cross-border interconnection points (IPs), figures in GW_{th} for 2032 based on calorific value



Source: Transmission system operators

Further information on the entry capacities at the cross-border IPs can be found in the Appendix.

Table 2 shows the hydrogen entry capacities and quantities for the year 2032 in total, while in Figure 2 they are shown for every region at district level. The calculated total output is taken into account for modelling of the hydrogen core network.

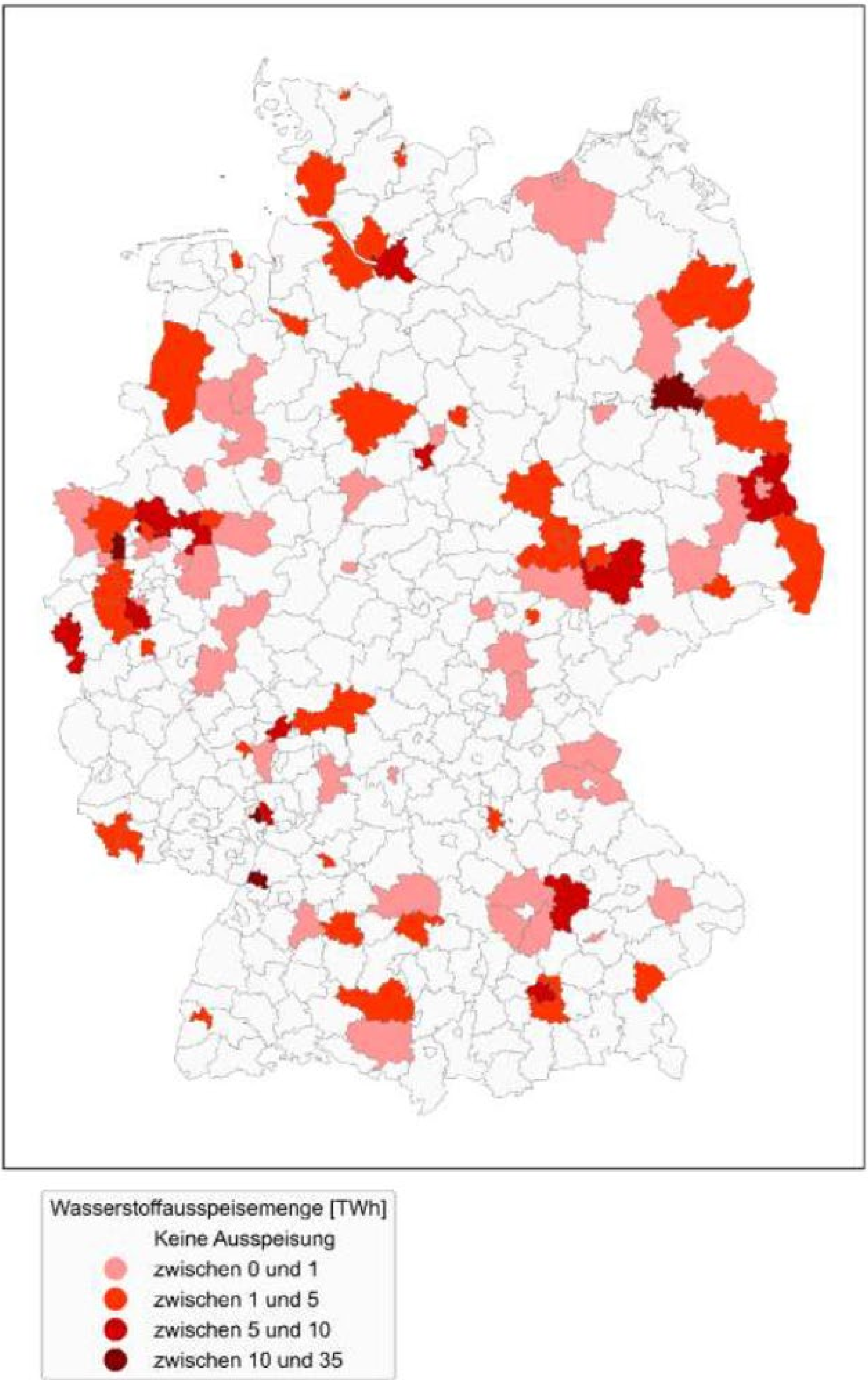
Table 2: Exit capacities and quantities for hydrogen by criteria, data for 2032 based on calorific value

	Ausspeiseleistung* [GW_{th}]	Ausspeisemenge* [TWh_{th}], Brennwert
Gesamt	**87**	**279**
- davon IPCEI-, PCI- und Reallabor-Projekte	10,3	49
- davon Projekte zur Einbindung in ein europäisches Wasserstoffnetz	0,3	0
- davon Eisen und Stahl	7,8	50
- davon Chemie	5,2	32
- davon Raffinerien	4,2	30
- davon Glasindustrie, inkl. Glasfaser	0,4	2
- davon mittlere bis große Produktionsstätten für Keramik und Ziegelprodukte	0,2	1
- davon KWK-Anlagen	62,0	157
- davon Speicher	7,6	11

* Double counting is possible, i.e. a project can be assigned to several criteria.

Source: Transmission system operators

Figure 2: Exit quantities for hydrogen at district level in the scenario for the hydrogen core network, data for 2032 in TWh as calorific value



Source: Transmission system operators

3 Pipeline notifications from potential hydrogen network operators

With the publication of the current planning status for a supra-regional hydrogen core network on July 12, 2023, operators of gas distribution networks, hydrogen network operators and operators of other pipeline infrastructures were also given the opportunity to comment and report further hydrogen infrastructures for the hydrogen core network in accordance with Section 28r (5) EnWG-E. The e-mail address info@fnb-gas.de and a special form for pipeline notifications, which can be downloaded from the FNB Gas website, were available for providing feedback to FNB Gas.

The transmission system operators received a total of 62 responses. In addition to notifications of pipelines, the transmission system operators also received comments that were not exclusively pipeline notifications. In particular, if these comments concerned the scenario developed under the leadership of the BMWK and the BNetzA, these respondents were referred to the parallel opportunity opened up by the BMWK for the federal states, associations and other stakeholders to submit comments. In this case, comments could also be submitted directly to the BMWK before July 28, 2023.

In the following, the transmission system operators briefly describe the main aspects of the pipeline notifications:

With the 62 responses, the transmission system operators have received a total of 99 pipeline notifications from 26 potential hydrogen network operators. The reported pipelines are technically very heterogeneous. The nominal diameter is between DN 40 and DN 1000, the lengths vary from 0.1 km to 92 km, and the maximum permissible operating pressure MOP is between 8 barg and 100 barg. The total length of the reported infrastructures is around 1,400 km. Of these, around 40 km are already in use today (hydrogen), around 300 km constitute new construction and around 1,060 km conversions.

Of the 99 reported infrastructures, ten pipelines were withdrawn and 18 pipelines did not meet the criteria, so in the end 71 pipeline notifications from other potential hydrogen network operators were considered for modelling.

The 18 pipelines that did not meet the criteria were excluded for the following reasons (see Annex 2):

- Due to a change of ownership in the meantime, five pipelines are to be allocated to the transmission system operators and are therefore not included as pipeline notifications in Annex 2, but as TSO pipelines in the draft application (Annex 3).
- Five pipelines are not considered due to low pressure levels.
- Five pipelines cannot be used in the scenario due to the distance to the hydrogen core network and the lack of customer demand.
- Three pipelines are not included due to late conversion/completion (after 2032) or uncertain planning status.

The remaining 71 pipeline notifications had a total length of around 980 km and were checked as part of the modelling process for the hydrogen core network. The final results can be found in section 5.4 and in Annex 2.

4 Modelling the hydrogen core network 2032

The following section describes the basic parameters for modelling. First, the basic planning principles are presented (see section 4.1). This is followed by a description of the transmission infrastructures (see section 4.2), which form the basis for modelling the hydrogen core network. The basic modelling procedure is then explained (see section 4.3). Finally, the load cases for modelling the hydrogen core network are presented (see section 4.4).

4.1 Basic planning principles and assessment of alternatives

Basic planning principles

The basic planning principles according to which the transmission system operators have determined the hydrogen core network are specified in Section 28r (1) sentence 2 of the amended EnWG:

"The aim is to establish a ***Germany-wide, efficient, rapidly realizable and expandable hydrogen core network*** *that contains all effective measures to connect the future key hydrogen production sites and potential import points with the future key hydrogen consumption points and hydrogen storage facilities."*

In particular, the specific description of maxims clearly shows that the principles of "Germany-wide", "efficient", "quickly realizable" and "expandable" must be followed in the planning of the hydrogen core network.

In this context, efficiency means, among other things, that the plans for a hydrogen core network must be set out in such a way that interventions in the environment and nature are kept to a minimum. The hydrogen core network in its target state must also be highly effective in terms of meeting future requirements, and that initial implementations are possible in a timely manner.

Efficiency also means cost-efficiency. Conversion of existing pipeline infrastructure is always preferable for cost reasons. This is simply because converting pipeline infrastructures requires only around one fifth of the investment needed for construction of new hydrogen pipelines. In addition, converting pipeline infrastructure can be done much faster than new construction. However, new construction is generally necessary if there are few conversion options or none at all because there is no infrastructure in place, or if the infrastructure to be converted is too small.

A strategic expansion is therefore efficient and meaningful, based on adequate dimensioning and focusing on the robustness and resilience of the network with regard to its future requirements through efficient, demand-oriented scalability. Scalability can be realized through planning that allows a subsequent increase in transmission capacity, which is achieved with an increase in the effective pipeline pressure through additional installation of compressors along the pipeline route.

When deriving the principles for network planning, planners should also note that transmission capacity competes with the flexibility required for operational processing (depending on the network access regime).

The main factors influencing the potential (transmission and flexibility) of the network are:

- Network geometry (volume): larger nominal diameters are advantageous here.
- Pressure barriers (technical, contractual): a high-pressure design is advantageous (operation far from the design pressure).
- Pressure load change: high pressure and larger diameters are advantageous.

It is important to bear in mind that dimensioning and spatial development are sometimes contradictory aspects. Reducing the dimensions of a new hydrogen pipeline by one or two diameter classes can justify 30% to 50% of the length of an additional new pipeline. This is cost-neutral, as very large diameter classes are very expensive. These additional new pipelines can open up further regions, strengthen the cross-connection of the infrastructure and increase the security of supply.

A reduction in the diameter classes also has further positive effects in terms of cost efficiency and rapid feasibility.

From a diameter greater than DN 1200, pipeline construction requires sophisticated technical solutions as the nominal diameter increases, such as the use of larger construction machinery and the handling of greater tonnages. These, in addition to technical aspects, limit the range of suppliers and availability. Large diameters also have an impact on civil engineering, including dewatering; each water crossing is therefore enormously complex and could result in a much greater impact on the protected assets (nature and soil conservation).

To summarize, for dimensioning, it is important to ensure that the objectives are checked against the advantages and disadvantages. For example, large diameters offer advantages in terms of network geometry (pipe volume, transmission capacity), but there are also disadvantages on the cost and execution side (approval and deadline risks).

Ultimately, experience shows that dependence on individual gas importers is relevant to security of supply. It is therefore important to ensure the spatial and temporal transportability of hydrogen from the outset and to guarantee a rapid ramp-up to create a hydrogen core network. In order to reduce dependency, the network needs several high-capacity import points as part of a European network as well hydrogen storage capacities. Security of supply can be ensured through the robustness and resilience of the hydrogen core network, which can be achieved through diversification, among other things. Several reliable sources should therefore be developed and a good degree of cross-connection aimed for in the hydrogen core network. The transmission system operators assume that this is achieved, among other things, by the logic of freely allocable capacities (FACs) applied in the load cases and the design with the appropriate diameters and pressure levels.

Examination of alternatives

Against the background of the legal requirement pursuant to Section 28r (2) sentence 2 EnWG, the transmission system operators have examined the results of the hydrogen core network for possible alternatives that are more cost-efficient.

The aim of the assessment of alternatives is to demonstrate specifically that the pipelines to be converted and newly constructed, as identified and proposed in the draft application for the hydrogen core network, and their ancillary facilities represent the most cost- and time-efficient solutions in the long term.

For conversion pipelines, the assessment of alternatives is based on an investment comparison with a possible new construction of a hydrogen pipeline instead of a conversion. In addition to the original costs of an individual pipeline conversion, the cost of the corresponding project to reinforce the natural gas infrastructure is also included in the cost comparison. Where a natural gas reinforcing measure is assigned to several conversion projects, the costs of these natural gas reinforcing measures are allocated proportionately. Examining the extent to which natural gas reinforcing measures allow a natural gas pipeline to be converted to hydrogen also means following the concept of efficiency. If fewer measures are required for natural gas than for hydrogen, these will be given priority in the planning in order to follow the principle of cost-efficiency and faster implementation.

The assessment of alternatives for new pipelines follows the approach of analysing whether a possible conversion of existing gas infrastructure of the transmission system operators or natural gas pipelines reported by other potential hydrogen network operators should be given preference over a newbuild project. This consideration also includes examining whether a new pipeline is fundamentally necessary due to the lack of conversion pipelines. The review is based on the following criteria:

1. A pipeline which could potentially be converted is still required in the methane network and cannot be compensated by comparatively inexpensive measures
2. The pipeline which could potentially be converted is too small
3. A new pipeline has to be built as there is no pipeline that can be converted
4. The new pipeline serves to develop new production or demand areas in the sense of a regional balance
5. There is no need for other new pipeline routes
6. A new pipeline is not economically viable compared to a compressor
7. Compression or higher upstream pressure by foreign transmission system operators

Criteria 6 and 7 relate to the construction of new compressor stations.

When deriving the principles for network planning, planners should also note that transmission capacity competes with the flexibility required for operational processing (depending on the network access regime).

The results of the assessment of alternatives for the converted and newly built pipelines are presented in Annex 3 to the hydrogen core network. In addition, section 5.5 describes the measures that have been omitted compared to the planning status of July 12, 2023.

4.2 Transmission infrastructures as a basis for modelling

The following transmission infrastructures in particular were used as the basis for modelling the hydrogen core network:

- The hydrogen network of the Gas Network Development Plan 2022-2032
- Pipeline infrastructures from IPCEI, PCI and real laboratory projects
- Pipeline notifications from other potential hydrogen network operators (see section 3)

As part of the modelling, various load cases are used to check which pipelines are required for an efficient, functioning hydrogen network and whether additional pipelines may be required. Furthermore, the necessary compressor stations are determined as part of the modelling.

4.3 Basic procedure

The entire modelling process flow is shown schematically in Figure 3.

Figure 3: Process steps for hydrogen network planning

Source: Transmission system operators

Description of the individual process steps

0. Scenario

- The modelling is based on the coordinated scenario for the hydrogen core network. The basic procedure and the results are described in section 2.

1. Modelling preparation

- The transmission system operators implement the transmission infrastructures and create a functional modelling basis in the calculation model.
- Entry and exit capacities to be taken into account are assigned to suitable network connection points of the transmission infrastructures.
- Assumptions are defined for the modelling (e.g. feed-in temperatures and transfer pressures).

2. Development of load cases for a functional and reliable hydrogen core network

- The transmission system operators develop different flow situations based on defined load cases in order to carry out load tests of the infrastructure.
- The conditions for the utilization of the entry and exit points are defined in a load case.

3. Network simulation and overall network analysis I

- The transmission system operators carry out a network simulation and check whether the infrastructure taken into account to date is sufficient and adequate to meet transmission requirements.
- The test is carried out on the basis of the defined load cases.

4. Infrastructure update

- If the planned infrastructure cannot meet the transmission requirements, the transmission system operators include additional pipelines and compressors to eliminate bottlenecks. Infrastructure elements that were not required in the previous network simulation can also be removed again (optimization).
- Existing pipelines as well as new-build pipelines, pressure regulating systems, valves or compressors can be part of the modelling.

5. Network simulation and overall network analysis II

- The transmission system operators carry out a network simulation based on the revised infrastructure and check whether it is sufficient and adequate to meet the transmission requirements.
- The transmission system operators carry out an optimization of the alternative solutions, applying further assumptions if necessary.
- If the infrastructure is sufficient to cover the transmission requirements and no more scope for optimization is identified, the modelling process ends.

6. Publication

- The results of the hydrogen core network will be published as part of the BNetzA's consultation process.

4.4 Definition and results of the load cases

Load cases

To design the hydrogen core network, it is necessary to consider different load cases in order to ensure resilience with regard to significantly different load situations and free allocability of the specified capacities.

The basis for deriving the load cases is the scenario for the hydrogen core network developed for this purpose under the leadership of the BMWK and the BNetzA and agreed with the transmission system operators based on the assumptions for entry and exit capacities described in section 2.

The main feature of the various load cases is the testing and design of the network with regard to different regional distributions of entry and exit loads. For this purpose, Germany is divided into different regions (North, West, East, South), which are then tested diametrically with their spatially assigned entry and exit loads. This means, for example, that if all entries in the North are tested in terms of transmission capacity or free allocability, then this results in a diametrical effect in the South which then has to cope with high exit loads.

Figure 4: Regions of the load cases considered on entry side*

* Shaded areas are contained in two regions: Rhineland-Palatinate/Saarland in West/South, Schleswig-Holstein in North/East.

Source: Transmission system operators

In addition, structurally different load cases are defined to reflect the load and distribution across Germany. A distinction is made between autumn, winter and no-wind/no-sun load cases, which essentially differ in terms of the level of load, especially in winter, due to the temperature-dependent CHP capacity. As the hydrogen network sees a much lower load in summer due to lower consumption, it is not necessary to consider a separate summer load case for network design purposes.

The transmission system operators have identified a total of six so-called "restrictive" load cases for the network design, which are described below:

No wind, no sun conditions

In this scenario, wind and solar plants generate little electricity over a limited period of time due to weather conditions, which is why electrolysers do not produce or feed in any hydrogen during this time. In this case, electricity consumption is covered by dispatchable capacities, in particular CHP plants. Only non-volatile entries were used to cover the balance. This situation requires a network-stabilizing withdrawal of hydrogen from storage. At the same time, it is assumed that all available hydrogen CHP plants are used in order to provide both heat and electricity for the transmission network.

- Entry capacity:
  - Volatile entry projects 0 %, non-volatile entry projects incl. cross-border IPs 100 %,
  - Storage 100 %.
- Exit capacity:
  - CHP 100 %, industry 100 %, storage 0 %.

Winter load case

In the winter and autumn load cases, the transmission system operators test whether the regionally bundled entry capacities assumed in the scenario can be managed simultaneously.

Due to the high entry capacities in the north, a winter load case is only tested for maximized northern entries. For this purpose, rather low off-takes in the north are compared with high off-takes in the south with simultaneously low entry capacities in the south in order to test a maximum restrictive transmission case in winter. Withdrawal from storage is not used in this load case in order to not increase the grid load which is already high due to the entries in the north. Instead, "integrated storage usage" is assumed, where there is either injection into storage or the storage facilities are not used. The latter is less useful for network operation in this situation and is therefore assumed.

The CHP off-takes are taken into account depending on the regional design temperature. For this purpose, a temperature analysis was carried out across the whole of Germany.

In the first step, the average daily air temperatures at a height of two meters were determined using data from the Climate Data Centre of the German Weather Service at 21 representative measuring points selected in the vicinity of the largest reported CHP plants over an observation period of approx. ten years (January 1, 2013, to June 11, 2023). The temperature data was consolidated in five regions (Bavaria/Baden-Württemberg, NRW/ Rhineland-Palatinate/ Saarland/Hesse, Schleswig-Holstein/Bremen/Lower Saxony/ Hamburg, Mecklenburg-Western Pomerania / Berlin/Brandenburg, Saxony/Saxony-Anhalt/Thuringia) in order to take into account different temperature ranges occurring simultaneously in Germany. It was assumed that the maximum CHP offtake in the diametrically opposed southernmost federal states of Bavaria and Baden-Württemberg occurs at the lowest mean daily temperature (TM_{min}) measured during the period under consideration (reference value) and this was compared with the highest mean daily temperatures (TM_{max}) measured on the same day in the other regions.

The following temperatures were determined for February 10, 2021, the day with the lowest mean daily temperature (TM_{min}) in Bavaria and Baden-Württemberg during the period under consideration:

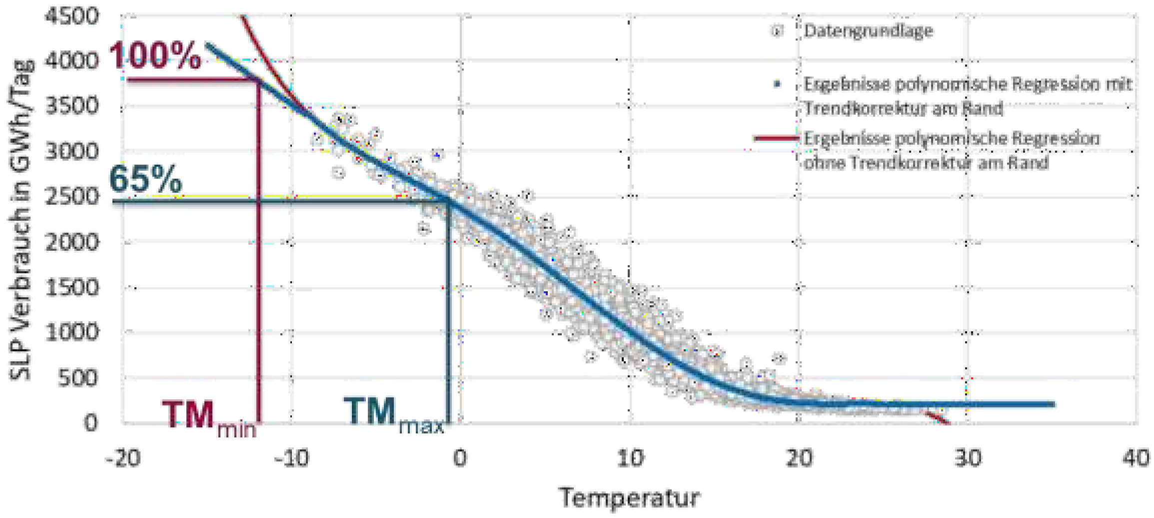
Table 3: Lowest and highest daily mean temperatures on February 10, 2021, by region

	Unit	BY/BW region	Region MV/BB/BE	TH/ST/SN region	Region SH/HH/NI/HB	Region NW/HE/SL/RP
TMmin	°C	-11,4				
TMmax	°C		-1,4	-2,7	-2,7	-1,4

Source: [German Weather Service, 2023]

In the second step, the temperature data obtained was used in a polynomial regression of the BDEW (German Association of Energy and Water Industries), which estimates the SLP gas consumption depending on the weighted average daily temperature. The standard load profile (SLP) was used because it provides a good representation of the heating load behaviour, which can also be assumed as a first approximation for the heat-led use of the CHP plants.

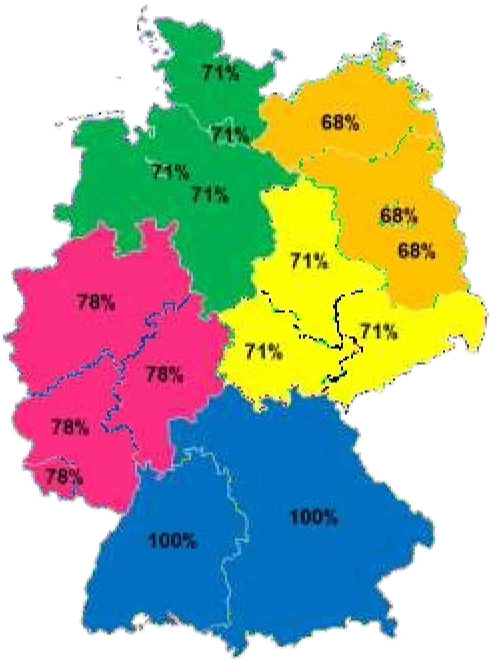
Figure 5: Determination of scaling factors for the CHP exit capacities using a polynomial regression



Source: Transmission system operators, adapted from [BDEW, 2022]

The scaling factors determined in this way are shown in Figure 5.

Figure 6: Temperature-dependent CHP feed-in power for the winter load case



Source: Transmission system operators

The result of the analysis showed a range of 68 % to 78 % of the maximum temperature-dependent reductions of the other federal states in the case that the southern federal states are close to the design temperature (at maximum reduction). Depending on the federal state, this 68 % to 78 % is used as relief potential through CHP.

- Entry capacity:
  - Entry projects incl. border crossing 100 % in the North region, storage 0 %,
  - Other entries to cover the balance, with priority given to those located as far north as possible.
- Exit capacity:
  - 100 % of the possible exit capacity in the southern region, injection into storage not used,
  - 20 % remaining federal states, CHP between 68 % and 78 % depending on the federal state, storage 0 %.

Autumn load cases

In the four autumn load cases, the maximum entry capacities (without storage) are applied for each region based on the four regions formed – North, West, East and South. There is also examination of whether a Germany-wide demand of 20 % can be covered. 20 % roughly corresponds to the base load of industrial customers in today's natural gas network. If there is a surplus of entry capacity, the most distant exits are also increased until balancing is achieved.

- Entry capacity:
  - For entry projects 100 % in the respective region, 0 % in the other regions,
  - Storage facilities 0 %.
- Exit capacity:
  - At least 20 % for industry, CHP and storage.

Due to similar temperatures in autumn and spring, spring load cases do not have to be considered separately.

5 Hydrogen core network 2032

The next section presents the results of the modelling exercise. Following an outline of the procedure with connecting pipelines (cf. section 5.1) and with pipelines of other potential hydrogen network operators that were taken into account in the modelling process (cf. section 5.2), the results for the hydrogen core network (cf. section 5.3) are shown. Section 5.4 provides an overview of the included and excluded pipelines of other potential hydrogen network operators for this hydrogen core network. The changes to the hydrogen core network compared to the planning status of July 12, 2023, can be found in section 5.5.

5.1 Dealing with connecting pipelines

According to Section 28r (1) sentence 2 EnWG-E, the aim of the hydrogen core network is *"to establish a Germany-wide, efficient, rapidly realizable and expandable hydrogen core network that contains all effective measures to connect the future key hydrogen production sites and potential import points with the future key hydrogen consumption points and hydrogen storage facilities."* So-called connecting pipelines are not part of the hydrogen core network. For this delimitation, the transmission system operators have developed criteria for the definition of connecting pipelines, and this forms the basis for classification of connecting pipelines.

The transmission system operators point out that these criteria for defining connecting pipelines only apply to the hydrogen core network. For further integrated network development planning (hydrogen and methane), the transmission system operators assume that the basic criteria for network connection processes will then be applied, similar to those already used for methane.

The transmission system operators do not consider themselves responsible for checking whether the pipelines of other potential hydrogen network operators are connecting pipelines. Therefore, all pipelines of other potential hydrogen network operators that can be reasonably used in the hydrogen core network will be considered. The decision to include the pipelines of other potential hydrogen network operators in the hydrogen core network is ultimately made by the BNetzA together with the respective potential hydrogen network operators.

The transmission system operators have developed five criteria for the definition of connecting pipelines based on various parameters. Inclusion in the hydrogen core network is checked on the basis of the following criteria and test questions:

1. Has an IPCEI application been submitted for the pipeline?
2. Is the pipeline a conversion line?
3. Does the pipeline have a diameter greater than DN 300 (transport character)?
4. Is the pipeline integrated into the overall network (regional development)?
5. Is more than one customer connected to the pipeline?

All pipelines for which an IPCEI application was submitted were included in the list of measures for the hydrogen core network. If no IPCEI application was submitted for the pipelines, the assessment was based on the other criteria (assessment questions 2 to 5). Where all test questions 2 to 5 are answered with "no", such a measure is defined as a connecting pipeline. If one of the test questions 2 to 5 is answered with "yes", it is not a connecting pipeline.

5.2 Dealing with pipelines of other potential hydrogen network operators included in the modelling

In the framework of the opportunity to comment on the planning status document between July 12, 2023, and July 28, 2023, other potential hydrogen network operators submitted pipeline notifications for the hydrogen core network (see section 3).

The transmission system operators have checked whether pipelines reported by other potential hydrogen network operators meet the technical requirements for integration into the hydrogen core network and whether this infrastructure can be used for the transmission requirements. The other potential hydrogen network operators who submitted pipeline notifications for the hydrogen core network were informed by the transmission system operators whether or not their pipeline notifications were taken into account in the draft hydrogen core network.

Annex 2 to the draft joint application for the hydrogen core network lists the pipeline notifications of the other potential hydrogen network operators and, in particular, the reasons for not considering individual pipeline notifications.

The transmission system operators point out that they cannot assess whether the remaining methane network can fulfill the capacity requirements in the respective distribution network if pipelines of other potential hydrogen network operators are converted.

In addition, some potential hydrogen network operators have made their pipeline applications subject to clarification of the regulatory and financial framework conditions for the hydrogen core network. Therefore, the transmission system operators cannot make a binding statement in the draft application for the hydrogen core network as to whether the pipelines of the other potential hydrogen network operators will be available for the hydrogen core network. The BNetzA must examine this and, in accordance with Section 28r (6) sentence 4 EnWG-E, oblige the other potential hydrogen network operators to make their pipelines available in a binding manner in its approval of the hydrogen core network.

5.3 Results of the hydrogen core network

Based on the scenario described in section 2 and the transmission infrastructures for the modelling (see section 4.2), the transmission system operators carried out network simulations for the hydrogen core network.

The presentation of results for the hydrogen core network includes the pipeline infrastructure (conversion and new construction pipelines, including the costs for ancillary facilities, in particular gas pressure regulating and metering systems) and compressor stations. Customer facilities for compression and metering at domestic feed-in points (e.g.

for electrolysers) and connecting pipelines are not included (see section 5.1).

The hydrogen modelling leads to the following overall results for the hydrogen core network:

Table 4: Results of the modelling for the hydrogen core network

	By the end of 2032
Technical parameters for the hydrogen core network	
Compressor stations [MW]	291
Pipelines [km]	9.721
- FNB pipelines to be converted	5.050
- New construction pipelines of the FNB	3.705
- Offshore pipelines of the FNB	256
- Pipelines of other potential hydrogen network operators to be converted	580
- New pipelines of other potential hydrogen network operators	130
- For information: Czech German Hydrogen Interconnector (CGHI)* [km]	168
Investments in hydrogen core network [billion euros]	
Compressor stations	1,7
Pipelines (incl. costs for ancillary systems, such as GPRM systems)	18,1
- FNB pipelines to be converted	3,1
- New construction pipelines of the FNB	12,8
- Offshore pipelines of the FNB	1,6
- Pipelines of other potential hydrogen network operators to be converted	0,2
- New pipelines of other potential hydrogen network operators	0,3
Total investments	**19,8**

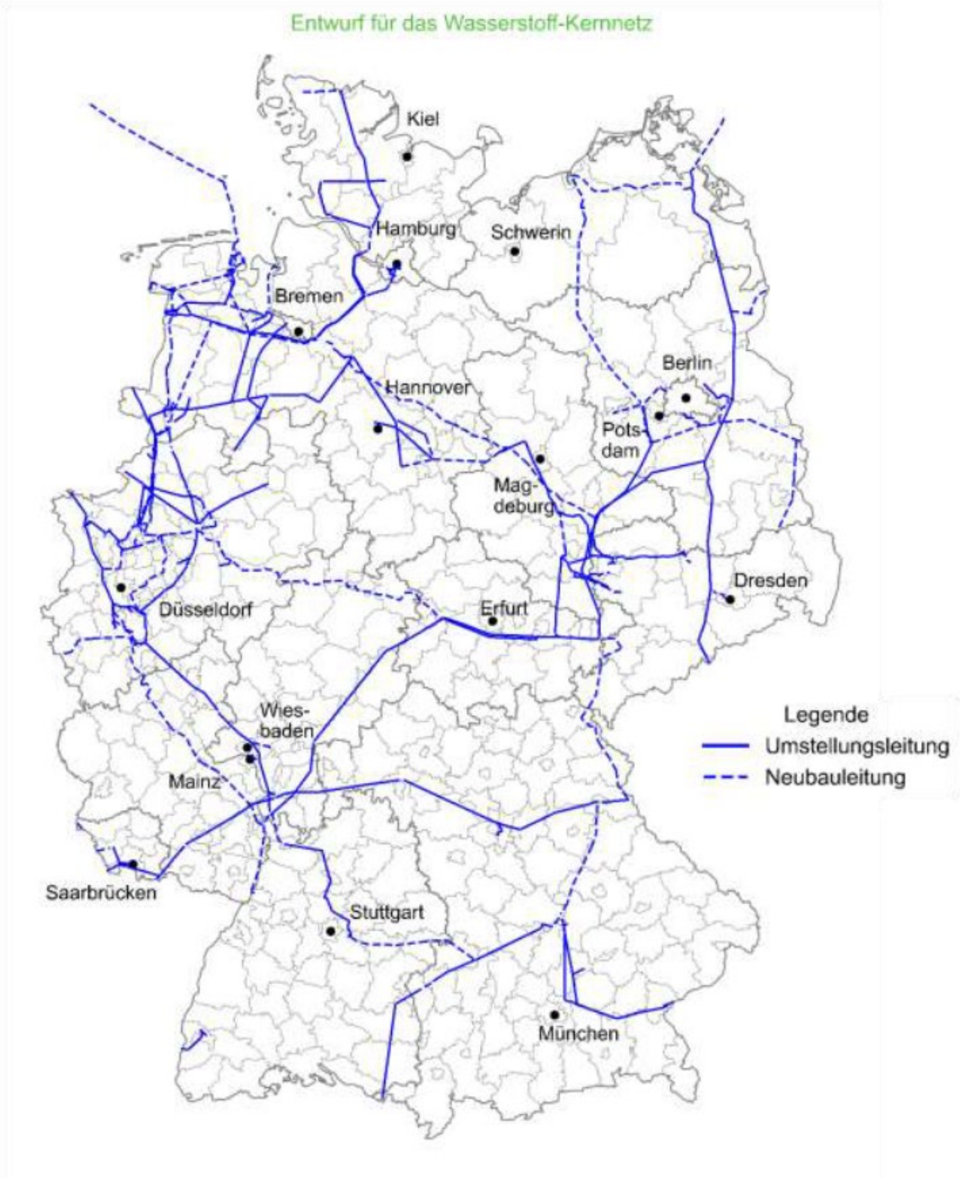
* CGHI was taken into account in the modelling but is not part of the hydrogen core network.

Source: Transmission system operators

Figure 7 below shows the draft of the hydrogen core network and the scope of the pipeline infrastructure with a total length of around 9,700 km. This includes the pipelines of other potential hydrogen network operators (cf. section 5.4). The following Figure 8 shows the location of the hydrogen core network in relation to the previously determined hydrogen feed-in and feed-out demand.

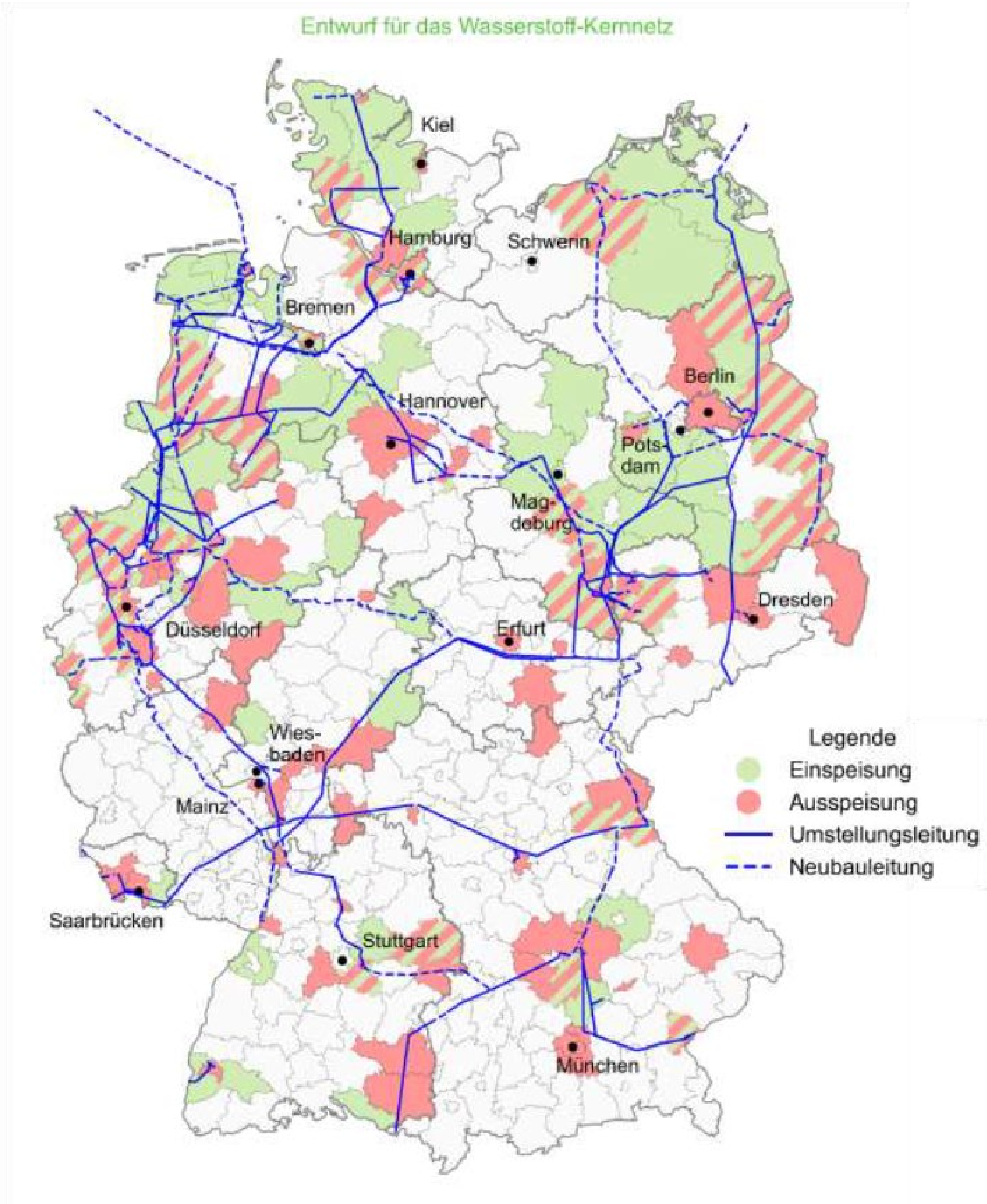
Annex 4 contains a detailed map of the hydrogen core network with an assignment of the ID numbers from annexes 2 and 3.

Figure 7: Result of the modelling of the hydrogen core network (incl. pipelines of other potential hydrogen network operators)



Source: Transmission system operators

Figure 8: Result of the modelling of the hydrogen core network, with feed-in and feed-out areas



Source: Transmission system operators

A detailed overview of all network expansion measures for the hydrogen core network can be found in Annex 3. It is not yet possible to provide a detailed description of ancillary facilities, in particular gas pressure regulating and metering systems, as the principles for network access, operation and control of the network have not yet been determined.

Figure 8 clearly shows that the hydrogen core network does not directly access all districts. Districts with hydrogen requirements for CHP plants that are not located directly on the hydrogen core network were taken into account in the hydrogen modelling in terms of capacity. These districts can be connected to the hydrogen core network as part of further future hydrogen network development. The following section looks at individual districts as examples.

The hydrogen demand of the city of Chemnitz is based on an existing CHP plant. This demand was set at the closest possible point in the hydrogen core network. The development can be examined as part of the network development planning for gas and hydrogen (Section 15a EnWG-E) as soon as concrete plans regarding the conversion of the CHP plant are available.

Demand in the southern region of Thuringia (Saalfeld-Rudolstadt district) meets the criteria for the hydrogen core network scenario and was set at the closest possible point. Based on the data of the hydrogen core network, the connection (also of other consumers) is planned in parallel, if necessary, as part of the network development planning for gas and hydrogen (Section 15a EnWG-E), so that the region can be connected and developed.

The demand in northern Bavaria (district of Kronach) meets the criteria for the hydrogen core network scenario and was set at the closest possible point. Based on the data of the hydrogen core network, the connection (also of other consumers) is planned in parallel, if necessary, as part of the network development planning for gas and hydrogen (Section 15a EnWG-E), so that the region can be connected and developed.

The hydrogen demand in the district of Deggendorf (administrative district of Lower Bavaria) is due to the CHP plant of an industrial company. This is not a local/district heating supply, but the heat generated is used in the company's production process. This district cannot be connected to the hydrogen core network via existing pipelines of the transmission system operators or via pipeline systems reported by other potential hydrogen network operators. The creation of a connection concept for the district of Deggendorf and the hydrogen development of the Lower Bavaria region is planned and can be included in the network development planning for gas and hydrogen (Section 15a EnWG-E).

The cost calculation, both for the pipelines of other potential hydrogen network operators and for the pipelines of the transmission system operators, was based on the guideline cost rates for transmission infrastructure assumed in the Gas Network Development Plan. They were expanded to include suitable factors to take into account the fundamental additional or reduced costs for hydrogen-compatible components as well as current findings. The transmission system operators refrain from publishing the indicative cost rates in this document due to possible market effects. For the above-mentioned reasons, a flat-rate approach based on the experience of the transmission system operators in terms of pipeline kilometres is used for the costs of the gas pressure regulating and metering systems. The cost figures for the other potential hydrogen network operators are cost estimates that have not been agreed with the relevant companies.

5.4 Consideration of the pipelines of other potential hydrogen network operators

When given the opportunity to comment on the planning status document of July 12, 2023, further potential hydrogen network operators submitted pipeline notifications for the hydrogen core network by July 28, 2023 (see section 3). The handling of pipelines of other potential hydrogen network operators included in the modelling was described in section 5.2.

A total of 26 other potential hydrogen network operators submitted 99 pipeline applications. Following a review of the criteria, 71 of these pipelines with a total length of around 980 km were included in the modelling of the hydrogen core network as potential hydrogen pipelines. As a result of the modelling, the transmission system operators propose including 56 pipelines from 17 other potential hydrogen network operators with a length of around 710 km, including possible connecting pipelines from other potential hydrogen network operators, in the hydrogen core network. This means that around two thirds of the pipeline notifications considered in the modelling will be included in the hydrogen core network. At 580 km, the largest share of this is accounted for by conversion and existing pipelines.

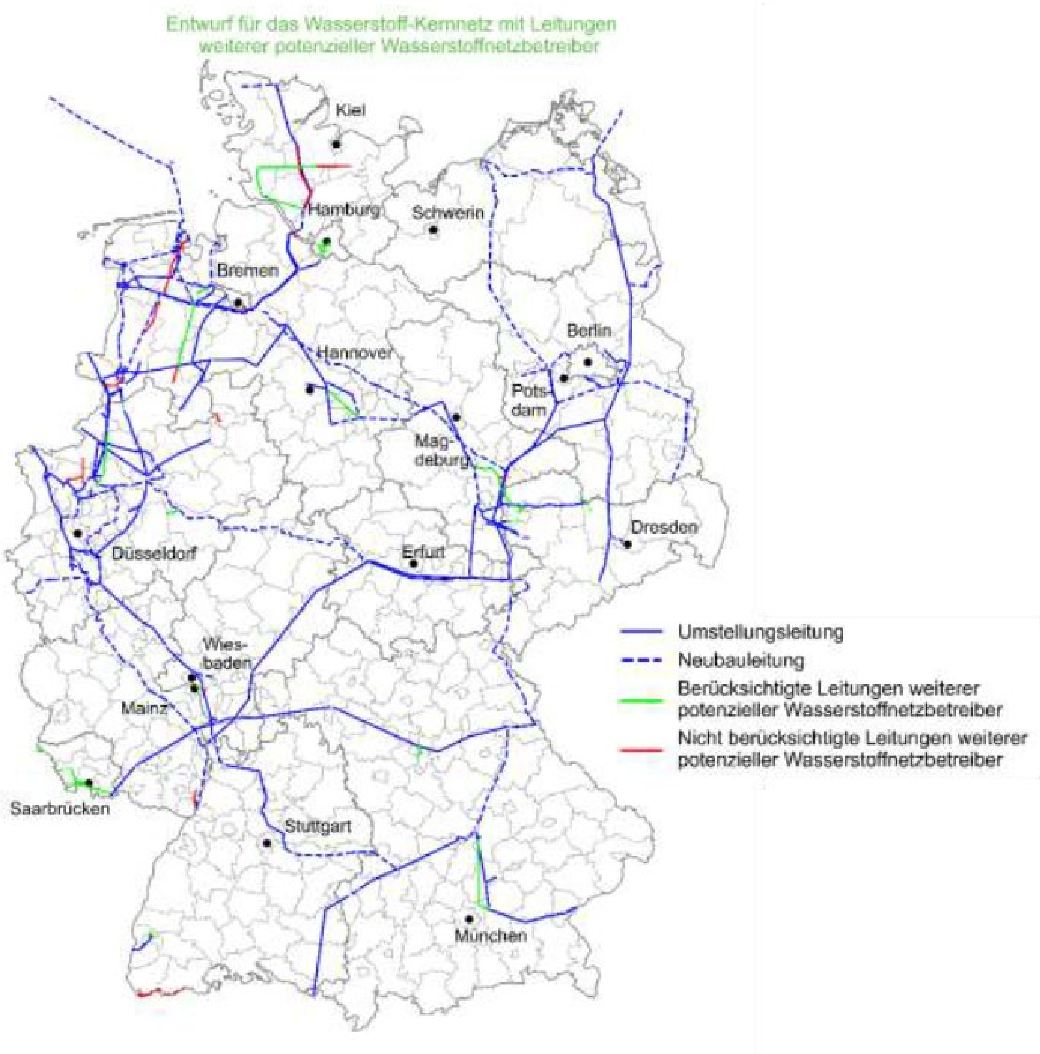
As a result of the modelling, a total of 15 reported pipelines of the other potential hydrogen network operators with a total length of around 266 km were not included in the hydrogen core network for the following reasons:

- Eight pipelines cannot be included in the scenario due to a lack of customer demand.
- For four of the pipelines, integration is not economically viable.
- Three pipelines cannot be used for onward transportation due to the pressure level.

Figure 9 below shows which pipeline notifications from other potential hydrogen network operators were included in the hydrogen core network and which were not.

Annex 2 to the draft joint application for the hydrogen core network lists the pipeline notifications of the other potential hydrogen network operators and provides specific reasons for the consideration or non-consideration of individual pipeline notifications. This also basically fulfils the requirements for the assessment of alternatives pursuant to Section 28r (2) EnWG-E.

Figure 9: Consideration of pipelines of other potential hydrogen network operators in the hydrogen core network

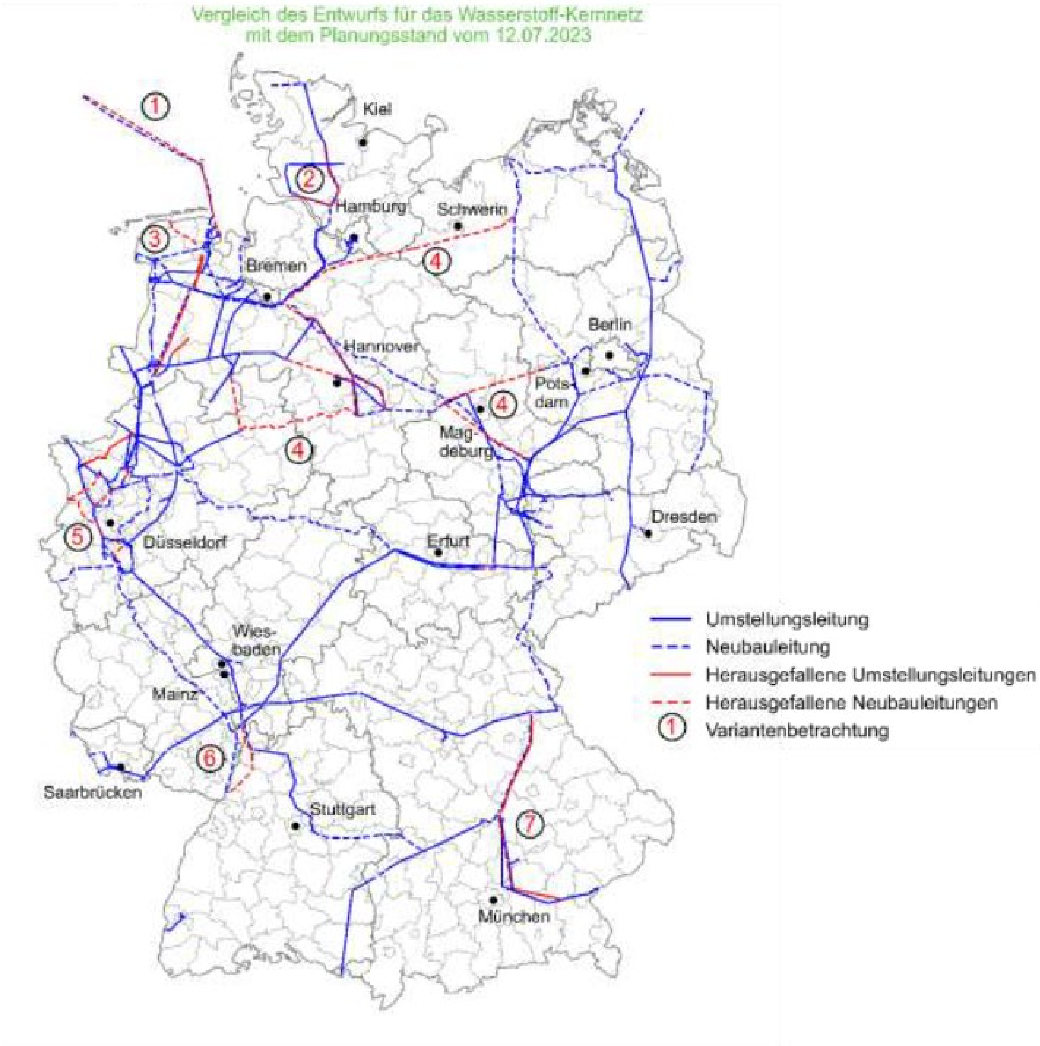


Source: Transmission system operators

5.5 Comparison of the hydrogen core network with the planning status of July 12, 2023

Figure 10 below shows the pipelines of the hydrogen core network in dark blue. At the same time, pipelines that have been omitted compared to the planning status of July 12, 2023, are shown in red.

Figure 10: Comparison of the hydrogen core network with the planning status of July 12, 2023



Source: Transmission system operators

The pipelines omitted compared to the planning status of July 12, 2023 (hereinafter referred to as the planning status) are considered as alternative pipelines as described below. The numbering of the variants in the following description corresponds to the presentation in Figure 10.

In addition to the variants described below, there are other smaller line sections that are not required in the modelling to cover the demand. These changes are not explained in detail, as they are not alternatives pursuant to Section 28r (2) EnWG-E.

1. Offshore North Sea
Two offshore pipeline routes were shown in the planning status. In the view of the transmission system operators, one offshore pipeline is sufficient to connect offshore hydrogen production in the German Exclusive Economic Zone (EEZ) and the import of hydrogen from the countries bordering the North Sea (NO, UK, NL or DK). Accordingly, the pipeline shown as number 1 in Figure 10 could be omitted. Due to its IPCEI status, AquaDuctus (offshore area SEN1 up to the German coast near Wilhelmshaven) was included in the hydrogen core network as an offshore pipeline.

2. Schleswig-Holstein
In the planning status, a new pipeline running in a north-south direction was planned for the transportation of hydrogen. In the current draft application, an existing pipeline was used instead to transport hydrogen and a corresponding natural gas reinforcing measure was taken into account to maintain security of supply for natural gas. The background to this is the assessment that this pipeline would not be required in subsequent network planning if methane transmission requirements – in particular exports to Denmark – could be reduced by mutual agreement. Denmark is already planning to be self-sufficient in its supply from 2027 by increasing biomethane production and reducing demand.

Natural gas transmission would be realized via an existing pipeline of a distribution network operator. Planning for this solution has already begun with the network operator.

It was possible to dispense with a new pipeline to Brunsbüttel compared to the planning status thanks to notification of an existing pipeline from a potential hydrogen network operator.

3. Wilhelmshaven area
In the planning stage, the Wilhelmshaven region showed various pipeline projects that were intended to fulfil the transmission task. In the region marked with the number 3 in Figure 10, a sensible solution was found as part of the iterations to optimize the hydrogen core network. For example, various project ideas for transporting the hydrogen output from Wilhelmshaven and Schillig (offshore landfall) were examined. Ultimately, two pipeline projects from the Etzel area in the direction of Barßel were eliminated. One pipeline project, which has IPCEI status, was relocated towards Bunde (application ID KLN046-01) instead of towards Barßel within the H2ercules project as agreed between the companies concerned and the responsible authority. An important alternative to the lines from Wilhelmshaven or Etzel to Barßel from the planning status is a line from the Wilhelmshaven area to Wardenburg (application ID KLN029-01), which is needed to cope with the considerable transmission demand to the east. In addition, a connection from Barßel in the direction of Wardenburg is required (application ID KLN024-01). This solution is much more favourable compared to the original planning approaches, as several partially parallel project ideas could be bundled here, and a technical solution was

found that corresponds with the planning of the west-east connections.

Furthermore, due to the choice of landing point, the originally planned connection to the North Sea in Dornum is no longer available.

4. West-east connections

In the planning variants, it was identified that a powerful east-west system in northern and central Germany supports the entire network very efficiently. The east-west connections bring flows to the efficient northeast-southwest existing system (Lubmin-Radeland-Bobbau-Rückersdorf-Reckrod-Lampertheim). The east-west connections also provide an efficient north-south transmission component. The high-capacity connections also achieve the desired cross-connection in the hydrogen core network and a very resilient structure in terms of the location of feed-in and feed-out capacity.

The transmission system operators have examined various options in order to develop a combination of high-capacity east-west connections. In principle, a combination of a new pipeline from Achim to Bobbau and another new pipeline from Werne to Eisenach was considered. Alternatively, a new line from Achim to Groß Tessin and several new lines to reinforce the existing infrastructure between Achim/Weser/Drohne/Bielefeld and Bobbau/Brandenburg a. d. Havel could be considered.

In later iterations, the new construction of the Achim-Hallendorf, Ahlten-Kolshorn cluster and Achim-Groß Tessin pipeline connections offered little added value for a high-capacity connection between eastern and western Germany and were therefore discarded as possible options. A conversion of existing infrastructure could still be used to supply the Hanover area with hydrogen. In addition, it was possible to dispense with the construction of new connecting lines between Wefensleben-Bobbau and Wefensleben-Brandenburg a. d. Havel.

The new Wefensleben-Brandenburg a. d. Havel pipeline was not considered further in the network modelling, as the direct connection of an east-west connection from Wefensleben to Bobbau leads to a lower pressure loss and thus better supports transmission to the south.

In the course of the assessment of alternatives, the transmission system operators were able to identify the east-west connections Achim-Bobbau (KLN027-01, KLN-030, KLN012-01) and Werne-Eisenach (KLN098-01) listed in the planning status as the most efficient combination. The investments for this combination amounting to approx. EUR 2,038 million are offset by investments of approx. EUR 3,586 million for the alternative combination (Achim to Groß Tessin and Achim/Weser/Drohne/Bielefeld to Bobbau/Brandenburg a. d. Havel).

Table 5: Investment for the alternative combination Achim to Groß Tessin and Achim/Weser/Drone/Bielefeld to Bobbau/Brandenburg a. d. Havel

	Pressure stage	Diameter	Length	Investment
Line section	PN in barg	DN in mm	in km	in million euros
Achim - Groß Tessin	PN 80	DN 1200	257	1.086
Achim - Luttum	PN 80	DN 600	25	61
Luttum - Peine	PN 80	DN 1200	114	484
Peine - Sophiental	PN 80	DN 500	15	34
Sophiental - Hallendorf	PN 70	DN 400	22	8
Cluster Ahlten - Kolshorn	PN 80	DN 800	5	15
Weser - Lehrte	PN 80	DN 1200	63	267
Bielefeld - Lehrte	PN 80	DN 1200	135	569
Drone - Ummeln	PN 80	DN 1000	51	184
Wefensleben - Bobbau	PN 80	DN 1200	102	432
Wefensleben - Brandenburg a. d. Havel	PN 80	DN 1200	106	446
Total investment				**3.586**

Source: Transmission system operators

5. Ruhr area

In North Rhine-Westphalia, particularly in the Ruhr region and the Cologne area, the planning status of the hydrogen core network also offered several alternatives for fulfilling the transmission requirements. In the course of the modelling, the most suitable pipeline projects were selected, less efficient projects were withdrawn, and the nominal diameter of the selected projects was adjusted as required. The withdrawn projects are also shown in red in Figure 10.

No demand could be assigned to the **Gescher Süd-Wardt** conversion pipeline (as a double line between Bergerfurth and Wardt) in accordance with the agreed scenario. Due to the pipeline dimensioning in DN 200, the transmission capacity is limited and would not be able to replace any other pipeline project between Coesfeld and Krefeld. The transmission task from the developed load cases can be taken over by pipelines located further south (e.g. Dorsten-Hamborn pipeline). The pipeline will only be considered in the hydrogen network if the regional demand along the pipeline route can be covered.

The **Dorsten-Boy** pipeline was not included in the hydrogen core network, as the transmission task is taken over by part of the H2ercules project and the Dorsten-Recklinghausen connection. The pipeline rights are limited to DN 400 and a design with a larger nominal diameter seemed ambitious due to the dense development in this area. Thus, around 17 km of new construction (around 33 million euros) can be saved, and the demand allocated to the hydrogen core network in Gladbeck can be met.

There were two alternative routes for creating a connection between **Oberhausen and Duisburg Nord.** Here, the line route via Dinslaken was given preference, as it already integrates the Dorsten-Hamborn pipeline as an IPCEI project and the further route appears easier to implement than the variant through the densely built-up area in the north of Duisburg.

There were also two possible routes for the necessary new connection between **Duisburg North and Krefeld.** The southern route with a Rhine crossing near Krefeld was chosen. A feasibility study is already available for this route.

The **Venlo-Scholven** and **Venlo-Glehn** connections were not taken into account. With the Zevenaar cross-border IP and a NETG pipeline, a nearby import point is available with a transmission pipeline that is cheaper to convert and just as efficient. This transmission route is supplemented by the Krefeld-Duisburg Nord-Hamborn-Dorsten-Scholven connection. This potential was given preference over the Venlo cross-border IP. Investments of around EUR 43 million can be avoided on the German side alone.

The **Merkenich-Kalscheuren** connection (DN 700) was rejected as the Glehn-Kalscheuren (DN 400) and Glehn-Brühl (DN 900) transmission routes offer sufficient alternatives in terms of capacity. The Glehn-Kalscheuren transmission route can be realized to a considerable extent via conversion. Rights of way and approvals have already been obtained for some of the sections that need to be added to and will shorten the implementation period. Around 13 million euros in investments will be avoided.

6. Ludwigshafen-Karlsruhe area

The planning status in the Ludwighafen-Karlsruhe area originally included two connections (DN 800) from Lampertheim north of Ludwigshafen to Karlsruhe on both sides of the Rhine. In the course of modelling, it turned out that a new pipeline would be sufficient to fulfil the transmission task in the direction of Karlsruhe. For this purpose, the transmission route on the left bank of the Rhine via Ludwigshafen (KLN013-01) was preferred, as it is shorter and therefore cheaper than the alternative, omitted connection on the right bank of the Rhine east of Mannheim. In addition, the chosen option ensures an optimal regional balance, as the new Lampertheim-Heidelberg pipeline (KLN082-01) is already planned as a suitable measure for the development of consumption centres on the right bank of the Rhine in the Rhine-Neckar region. In addition, the planning status originally included two shorter connections to the existing lines converging in Lampertheim (KLU078-01, KLU021-01), one of which could be omitted. Overall, the pipeline lengths in the Ludwigshafen-Karlsruhe area were reduced by approx.102 km and the investment volume by around EUR 318 million in the course of the optimization.

7. Bavaria

As part of the optimization of the hydrogen core network planning, part of the entry capacity of 6.25 GWh/h at the Überackern cross-border IP was allocated to the southern Bavarian demand centres (including the chemical industry in Burghausen and Ingolstadt, as well as the greater Munich area). Compared to the planning status in July, this has a relieving effect on the connection of the southern Bavarian region to the MEGAL in Rothenstadt (see Figure 10). The consideration of the line infrastructure notifications 405-Finsing-Ismaning North and 406-Ismaning North-Münchsmünster from SWM-Infrastruktur additionally relieves the transmission route Haiming-Forchheim-Finsing.

Due to an adjusted design of the new compressor station to be built in Forchheim, the regional allocation, and the consideration of the aforementioned VNB pipeline infrastructure notification, the new construction measure between Forchheim and Finsing and the conversion of pipeline 308-Gröben-Finsing have been omitted compared to the planning status of the hydrogen transmission network.

The planning status of the hydrogen core network revealed a very high transmission requirement for the connection to southern Bavaria via the Rothenstadt-Forchheim route. The conversion of one of the two existing natural gas pipelines alone was not sufficient for this. It became necessary to build a new pipeline in addition to the conversion. This situation has been alleviated by the above-mentioned relief.

However, as more than ten natural gas customers are connected to the pipeline to be converted, who would then have to be reconnected to another natural gas pipeline, around EUR 100 million would have to be invested on top of the conversion costs of around EUR 52 million for these reconnections as natural gas reinforcing measures. This means that the costs for a conversion and a smaller new pipeline would exceed the costs for the solution proposed here of a single DN 1000 new pipeline. For the above-mentioned economic reasons, a pipeline conversion on the Rothenstadt-Forchheim route in the time horizon up to 2032 has been rejected in favour of the new pipeline.

The pipeline systems listed and the design of the compressor station in Forchheim ensure targeted, high-capacity transmission in and through Bavaria.

6 Identification of measures in the natural gas network to realize the hydrogen core network

In the interests of overall economically optimized planning, the 2032 hydrogen core network will be developed predominantly from converted pipeline systems of the existing natural gas infrastructure and from new hydrogen pipelines to be constructed. The transmission system operators thus meet the requirements of Section 28r (2) sentence 3 EnWG-E, according to which the possibility of converting existing pipeline infrastructure must be examined and presented as a matter of priority.

Accordingly, the transmission system operators have determined which pipelines in the 2032 hydrogen core network can be obtained through conversion of gas supply infrastructure. Here, there must be certainty at the time the infrastructure is converted to hydrogen that the remaining natural gas transmission network can meet the capacity requirements on which the scenario framework for the Gas Network Development Plan 2022-2032 is based.

With regard to the additional measures required in the natural gas network, the transmission system operators also point out that measures to reinforce the natural gas infrastructure must be approved together with the measures for the hydrogen core network:

The possibility of converting existing pipeline infrastructures examined by the transmission system operators in accordance with Section 28r (2) sentence 3 EnWG-E is regarded as a sub-case of the examination of alternatives to determine the most cost- and time-efficient solution in the long term. The conversion of existing natural gas pipeline infrastructures is therefore the result of a network optimization process that is regularly associated with further measures in the remaining natural gas transmission network.

As part of this conversion review, the transmission system operators must prove in accordance with Section 28r (2) sentence 5 EnWG-E *"that the natural gas infrastructure can be separated from the transmission system and that the remaining transmission system can meet the expected remaining natural gas demand at the time of conversion."* The proof can only be provided taking into account the measures required in connection with this, as the remaining natural gas requirements cannot be met otherwise. The BNetzA will only approve the application for the hydrogen core network in accordance with Section 28r (8) EnWG-E if the requirements of paragraph 2 are also met; the BNetzA must therefore check whether the proof of the conversion capability and the associated mandatory reinforcing measures for the natural gas infrastructure has been provided.

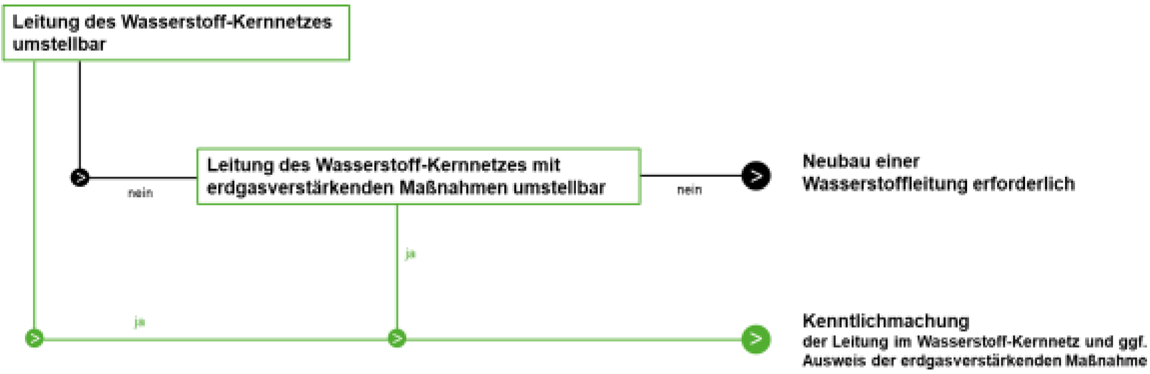
As these reinforcing measures are inextricably linked to the conversion of an existing pipeline infrastructure to hydrogen, they must also be approved as part of the hydrogen core network. The transmission system operators are obliged to make the conversion as part of with the approval granted in accordance with Section 28r (7) EnWG-E. They can only meet this obligation if they are also authorized to implement the reinforcing measures for the natural gas infrastructure from this point in time, and the obligation of the transmission system operators to implement the reinforcing measures ensures supply in the remaining natural gas system (the approval of the reinforcing measures for the natural gas infrastructure thus serves to ensure that the pipeline conversion can be approved).

6.1 Procedure

Based on the LNGplus security of supply variant C of the Gas Network Development Plan 2022-2032 and the identified hydrogen core network, the transmission system operators examined which gas supply infrastructure could be converted for hydrogen use in the hydrogen core network by 2032. A key prerequisite for classifying the convertibility of a gas supply infrastructure to hydrogen was that the capacity requirements identified in the LNGplus security of supply variant C can be covered by the remaining transmission network.

The procedure for identifying gas supply infrastructure for use in the 2032 hydrogen core network is shown schematically in Figure 11.

Figure 11: Procedure for determining gas supply lines for use in the 2032 hydrogen core network



Source: Transmission system operators

The transmission system operators used the infrastructure that was identified as necessary for use in the hydrogen core network to test its convertibility. For this gas supply infrastructure, they examined whether it could be converted to hydrogen use by the end of 2032. If a gas supply infrastructure cannot be converted, a further examination is carried out to determine whether it could be converted by taking measures in the natural gas transmission network (so-called "“reinforcing measures")” If conversion is possible in a cost-efficient manner by taking reinforcing measures on the natural gas side, the infrastructure also qualifies as convertible and the corresponding reinforcing measures are assigned to it. This may involve, for example, short new pipelines, partial parallelization of existing systems, the transfer of consumers and consumption areas to other natural gas pipeline systems, and the addition of compression capacity or gas pressure control and metering systems.

The possibility of converting existing pipeline infrastructures examined by the transmission system operators in accordance with Section 28r (2) sentence 3 EnWG-E is regarded as a sub-case of the examination of alternatives to determine the most cost- and time-efficient solution in the long term. The conversion of existing natural gas pipeline infrastructures is therefore the result of a network optimization process that is regularly associated with further measures in the remaining natural gas transmission network.

As part of this conversion review, the transmission system operators must prove in accordance with Section 28r (2) sentence 5 EnWG-E *"that the natural gas infrastructure can be separated from the transmission system and that the remaining transmission system can meet the expected remaining natural gas demand at the time of conversion."* The proof can only be provided taking into account the measures required in connection with this, as the remaining natural gas requirements cannot be met otherwise. The BNetzA will only approve the application for the hydrogen core network in accordance with Section 28r (8) EnWG-E if the requirements, in particular those set out in (2), are met; the BNetzA must therefore check whether proof of the conversion capability and the associated mandatory measures to increase the use of natural gas have been provided.

As these measures are inextricably linked to the conversion of an existing pipeline infrastructure to hydrogen, the natural gas reinforcing measures must also be approved as part of the hydrogen core network. The transmission system operators are obliged to convert with approval in accordance with Section 28r (7) EnWG-E. They can only comply with this obligation if they are also authorized to implement the natural gas reinforcing measures from this point in time, and the obligation of the transmission system operators to implement the natural gas reinforcing measures ensures the supply in the remaining natural gas system (the approval of the natural gas reinforcing measures thus serves to ensure that the pipeline conversion can be approved). Therefore, the transmission system operators will apply for approval of the conversion of the infrastructure to hydrogen, which is only possible with the implementation of the associated natural gas reinforcing measures, on the express condition that these natural gas reinforcing measures are approved.

6.2 Results

The following table shows the extent to which gas supply infrastructure could be converted to hydrogen use by 2032 and would therefore be available for the hydrogen core network. It also clearly shows the extent to which natural gas reinforcing measures are required for this.

Table 6: Gas supply infrastructure for use in the 2032 hydrogen core network

	By the end of 2032
Conversion of pipelines from methane to hydrogen [km]	
Pipelines that can be converted to hydrogen by 2032	**5.050**
- of which can be converted without natural gas reinforcing measures	1.647
- of which can be converted with natural gas reinforcing measures	3.403
Natural gas reinforcing measures - technical parameters	
- Compressor stations [MW]	97
- New lines [km]	602
Natural gas reinforcing measures - investments	
Measures to boost natural gas [billion euros]	**2,0**
- Compressor stations	0,5
- Cables	1,0
- Other measures (incl. reconnections, GPRM systems, valve stations)	0,5

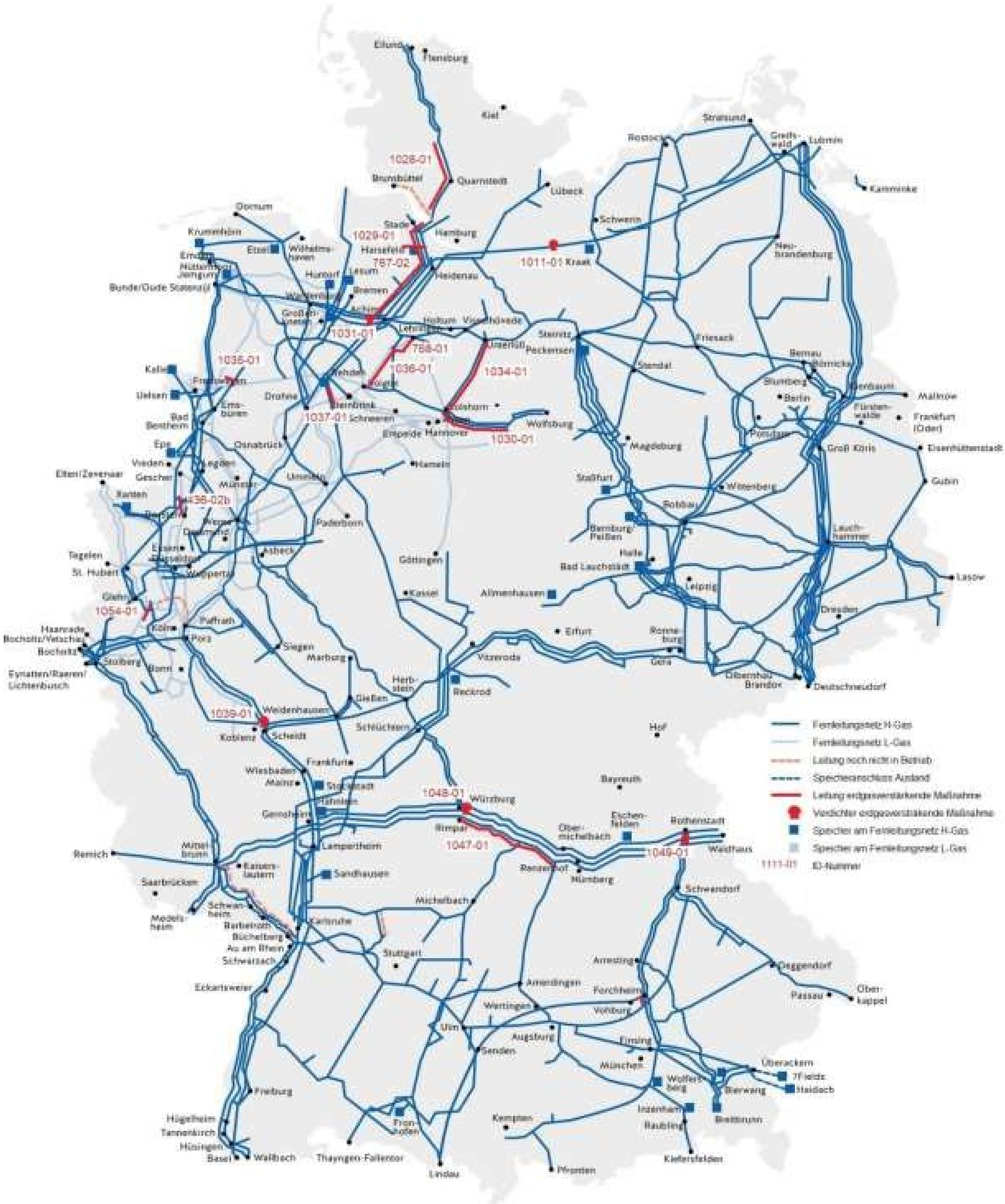
Source: Transmission system operators

Annex 3 shows the gas supply infrastructures that could be converted to hydrogen. The natural gas reinforcing measures required for the respective conversions to hydrogen are also assigned here. The natural gas reinforcing measures are also shown in this annex.

It is possible to convert gas supply pipelines with a total length of around 5,050 km by the end of 2032, whereby around 1,650 km can be converted without natural gas reinforcing measures and around 3,400 km with such measures. This means that around a third of the identified pipeline network can be converted without natural gas reinforcing measures. The costs for the natural gas reinforcing measures amount to around EUR 2.0 billion, which means that the 3,400 km mentioned above can be converted cost-effectively. Otherwise, significantly higher investments in the lower double-digit billion-euro range would be required for corresponding new construction of hydrogen pipelines.

The following figure shows the locations of the identified natural gas reinforcing measures. For reasons of clarity only, larger pipelines and compressor stations are shown on the map.

Figure 12: Natural gas reinforcing measures for the implementation of the hydrogen core network 2032



Source: Transmission system operators

Classification of the results

The determination of measures in the natural gas network to implement the hydrogen core network for the year 2032 is based on the LNGplus C modelling variant from the Gas Network Development Plan 2022-2032. The transmission system operators had no reason for a possible adjustment of the 2022 scenario framework, as provided for in Section 28r (2) EnWG-E.

However, against the backdrop of the current discussions on municipal heating plans as a central component of energy and climate policy, there are uncertainties regarding future capacity development. The transmission system operators will continue to monitor the development of the capacity requirements of the distribution system operators, in particular how these are embedded in municipal heating planning. The planned power plant strategy will also provide new impetus for the development of capacity requirements. The transmission system operators will therefore monitor the further development of CHP and power plant requirements, also in conjunction with the Electricity Network Development Plan.

The significant declines in output and volumes expected for the achievement of climate protection targets in terms of methane procurement with simultaneous changes in gas imports and storage use also lead to uncertainties. This may mean that in future, adjustments must be made to the scaling back of natural gas and the ramp-up of hydrogen, and may also have an impact on the required pipelines and conversion times. The resulting change in network load will significantly affect the possibility of making natural gas supply lines usable for hydrogen. At the same time, power plants and distribution network operators are substituting natural gas with hydrogen, which requires a corresponding hydrogen ramp-up. In an integrated network development planning process, the scenario can be adjusted taking into account the capacity requirements of the distribution network operators for natural gas and hydrogen.

According to estimates by the transmission system operators, the scope of natural gas reinforcing measures may be reduced in future network development plans. This presumed reduction in the measures required is due, for example, to the fact that a number of CHP plants and their output are included both in natural gas and in hydrogen in the planning for the hydrogen core network and in the planning for the Gas Network Development Plan 2022-2032. The aim of the transmission system operators is to resolve this double consideration in the upcoming network development plans.

In line with these developments, the determination of gas supply pipelines that can be converted to hydrogen use by 2032 is associated with uncertainties and must therefore be continuously reviewed as part of the new network development planning process that will be integrated in future.

Appendix

Explanations of cross-border IPs in the hydrogen core network

The integration of the German hydrogen network into a European hydrogen network is an important prerequisite for the functioning of the entire infrastructure. For the modelling of the hydrogen core network, the following assumptions were made at the cross-border IPs (see also Figure 1):

Denmark: Offshore connection to the Baltic Sea via the Bornholm-Lubmin interconnector

The planned entry capacity for hydrogen from Denmark to Germany at the offshore Baltic Sea cross-border IP was agreed between the technical experts at Energienet and GASCADE as part of the coordination process. The PCI projects Interconnector Bornholm-Lubmin (HYD-N-854/HYD-N-800) and Flow (HYD-N-796) under consideration serve to create a European hydrogen network for the transmission of hydrogen from Denmark to Germany within the meaning of Section 28r (4)(4)(d) EnWG-E.

Energienet has calculated an export capacity of 240 GWh per day for the upstream Danish hydrogen transmission project Interconnector Bornholm-Lubmin. A capacity of 240 GWh per day was agreed with the German partners for the cross-border IP. A total entry capacity of 10 GW was therefore assumed for Lubmin for the test year 2032.

In addition to the PCI project Interconnector Bornholm-Lubmin, the PCI project Baltic Sea Hydrogen Collector (PRJ-G-277) has been submitted by Gasgrid Finland Oy (Finland) and Nordion Energi AB (Sweden). With this PCI project, hydrogen is to be shipped from Finland and Sweden to Germany. The project participants have agreed to cooperate in order to avoid duplication of infrastructure. One result could be to integrate the Bornholm-Lubmin interconnector into the Baltic Sea Hydrogen Collector between Bornholm and Lubmin, especially if the hydrogen potential on Bornholm is not fully developed by 2032. The entry capacity of 10 GW assumed for Denmark is therefore to be understood as entry capacity from the Baltic Sea region (Denmark + Sweden + Finland).

Denmark: Ellund

The network operators Energinet and Gasunie have been working on the construction of a hydrogen connection between Denmark and Germany via the Ellund cross-border IP since 2020. As part of the cooperation, the basic feasibility of a connection was examined in an initial feasibility study in 2021. In 2023, the basic market assumptions were reassessed and confirmed in the Hydrogen Market Assessment Report [Energinet, 2023]. In principle, Denmark has very good locations for the generation of renewable energy/electricity (especially offshore wind). The generation potential clearly exceeds Danish demand, so it makes sense to use this generation potential to provide hydrogen for the German market as well. Denmark's good suitability for the production of hydrogen is also confirmed by the BMWK's long-term scenarios. Denmark's generation potential is already almost fully exploited in the T45 electricity scenario as part of the Europe-wide optimisation of the scenarios.

The export potential for hydrogen from Denmark currently agreed by Energinet and Gasunie is based on the Danish Energy Agency's’(DEA) medium pathway for the development of electrolysis in Denmark [Analyseforudsætninger til Energinet, 2022]. The capacities in the coordinated project applications for the 6th list of Projects of Common European Interest (PCI) were also determined on this basis (2.5 GW in 2030; 6.5 GW in 2035).

For the test year 2032, the DEA-AF22 figures result in a capacity of 4.3 GW of entry/exit capacity, which was applied at the Ellund cross-border IP.

Norway: Offshore connection to the North Sea via AquaDuctus

The estimated entry capacity for hydrogen from Norway to Germany was agreed as part of the German-Norwegian Energy and Industrial Partnership Joint Feasibility Study on Hydrogen with the involvement of FNB Gas, dena, Gassco and Equinor. Both IPCEI and PCI applications were submitted for the Norway-Germany transmission route. The various projects applied for, *CHE-pipeline, H2T project* and *AquaDuctus,* serve to create a European hydrogen network for the transmission of hydrogen from Norway to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

For the upstream Norwegian hydrogen transmission projects *CHE-pipeline* (HYD-N-1249), *H2T project* (HYD-N-884, HYD-N-1339), Equinor and Gassco have stated a total capacity of 820 GWh per day for their PCI applications. A capacity of 480 GWh per day was calculated for the AquaDuctus project, which is to be connected to the Norwegian PCIs. For imports to Germany, the German-Norwegian Energy and Industrial Partnership Joint Feasibility Study on Hydrogen estimated a capacity of 5 GW for the test year 2032.

For the connection of offshore hydrogen production in the German EEZ and the import of hydrogen from the countries bordering the North Sea (Norway, the United Kingdom, the Netherlands or Denmark), an offshore pipeline is sufficient from the perspective of the transmission system operators. Due to its IPCEI status, AquaDuctus (SEN1 up to the German coast near Wilhelmshaven) was considered as an offshore pipeline in the hydrogen core network. In addition to the 5 GW of import capacity assumed for 2032, the expansion stage of AquaDuctus included in the hydrogen core network can provide a prospective capacity of 20 GW for the intake of hydrogen from the North Sea. Additional densification (not part of the hydrogen core network) can further increase the import capacity to up to 30 GW.

Netherlands: Vlieghuis

The planned capacity for hydrogen from the Netherlands to Germany was agreed between Gasunie/Hynetwork Services B.V. (Netherlands) and Thyssengas GmbH (Germany) as part of the applications for the 6th list of Projects of Common European Interest (PCI). The proposed PCI projects "Hydrogen network phase 1" (NL) (HYD-N-468) and "Vlieghuis-Ochtrup" (DE) (HYD-A-906) serve to create a European hydrogen network for the transmission of hydrogen from the Netherlands within the meaning of Section 28r (4)(4)(b) of the draft Energy Industry Act"".

The projects are combined in Group HI WEST 26 ("Interconnection Netherlands-Germany at Vlieghuis")" Gasunie/Hynetwork Services and Thyssengas have calculated a capacity of 14.4 GWh per day from 2027 for the Vlieghuis cross-border IP for the joint PCI application. From 2029, a capacity of 19.2 GWh per day was reported, and from 2031 a capacity of 31.2 GWh per day. The proposed PCI "Vlieghuis-Ochtrup" (HYD-A-906) is part of the German hydrogen core network. Therefore, an entry and exit capacity of 1.3 GW was assumed in Vlieghuis for the test year 2032.

Netherlands: Oude Statenzijl/ Bunde

The planned entry capacity for hydrogen from the Netherlands to Germany at the Oude Statenzijl/Bunde cross-border IP was agreed between the technical experts from Hynetwork Services and Gasunie Deutschland as well as OGE and GTG Nord as part of the coordination processes. The Dutch Hydrogen Backbone, HyPerLink I, H2ercules and H2Coastlink projects under consideration serve to establish import opportunities for hydrogen from the Netherlands to Germany within the meaning of Section 28r (4)(4)(d) EnWG-E. In order to ensure European integration, the services at the cross-border IPs with the Netherlands were selected consistently with the planning of GTS and Hynetwork Services. A capacity of 4 GWh for 2032 was agreed with the German partners for the Oude Statenzijl/Bunde cross-border IP.

Netherlands: Elten

The planned entry capacity for hydrogen from the Netherlands to Germany at the Elten cross-border IP was agreed between the technical experts from Hynetwork Services and Open Grid Europe as part of the applications for the 6th list of Projects of Common European Interest (PCI). The various proposed projects, Dutch Hydrogen Backbone and H2ercules, serve to create a European hydrogen network for the transmission of hydrogen from the Netherlands to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

For the upstream Dutch hydrogen transmission project Dutch Hydrogen Backbone, HYD-N-468, Hynetwork Services has calculated a capacity of 76.8 GWh per day for the PCI application. For the Elten cross-border IP, a capacity of 76.8 GWh per day was agreed with the German partners for the H2ercules Network North-West project, HYD-N-1075, which is directly connected to the Elten cross-border IP. The proposed PCI H2ercules is part of the German hydrogen core network. For this reason, a total entry capacity of 3.2 GW was assumed in Elten for the test year 2032.

Netherlands: Vreden

The planned entry capacity for hydrogen from the Netherlands to Germany at the Vreden cross-border IP was agreed between the technical experts from Hynetwork Services and Open Grid Europe as part of the coordination process. The projects under consideration, Dutch Hydrogen Backbone and conversion of line 27 Vreden-Dorsten, serve to improve the import possibilities of hydrogen from the Netherlands to Germany within the meaning of Section 28r (4)(4)(d) EnWG-E.

Hynetwork Services has calculated an export capacity of 76.8 GWh per day for the upstream Dutch hydrogen transmission project Dutch Hydrogen Backbone. For the Vreden cross-border IP, a capacity of 76.8 GWh per day was agreed with the German partners for the conversion of line 27 Verden-Dorsten, which is directly connected to the Vreden cross-border IP. The conversion of line 27 Vreden-Dorsten is part of the German hydrogen core network. Therefore, a total entry capacity of 3.2 GW was assumed in Vreden for the test year 2032.

Belgium: Eynatten

The planned entry capacity for hydrogen from Belgium to Germany was agreed between the technical experts from Fluxys and Open Grid Europe as part of the applications for the

6th list of Projects of Common European Interest (PCI). The submitted Belgian Hydrogen Backbone and H2ercules projects serve to create a European hydrogen network for the transmission of hydrogen from the Belgian network to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

For the upstream Belgian hydrogen transmission project Belgian Hydrogen Backbone, HYD-N-1311, Fluxys has calculated a capacity of 91.2 GWh per day for the PCI application. For the Eynatten cross-border IP, a capacity of 91.2 GWh per day was agreed with the German partners for the H2ercules Network West project, HYD-N-1038, which is directly adjacent to the cross-border IP. The proposed PCI H2ercules is part of the German hydrogen core network. An entry capacity of 3.8 GW was therefore set in Eynatten for the test year 2032.

France: Medelsheim

The planned entry capacity for hydrogen from France to Germany was agreed between the technical experts from GRTgaz, GRTgaz Deutschland and Open Grid Europe as part of the applications for the 6th list of Projects of Common European Interest (PCI). The proposed projects H2Med, HY-FEN and H2ercules serve to create a European hydrogen network for the transmission of hydrogen from Portugal, Spain and France to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

For the upstream French hydrogen transmission project HY-FEN (H2 Corridor Spain-France-Germany connection), HYD-N-569, GRTgaz has calculated a capacity of 200 GWh per day for the PCI application, which is divided between the Franco-German cross-border IP and the smaller mosaHYc and RHYN projects close to the border. For Medelsheim, a capacity of 192 GWh per day was agreed with the German partners for the H2ercules Network South project, HYD-N-1052, which is directly adjacent to the cross-border IP. The proposed PCI H2ercules is part of the German hydrogen core network. An entry capacity of 8 GW was therefore set in Medelsheim for the test year 2032.

France: Freiburg

The planned entry capacity for hydrogen from France to Germany was agreed between GRTgaz and terranets bw as part of the applications for the 6th list of Projects of Common European Interest (PCI). The submitted RHYn and RHYn Interco projects serve to create a European hydrogen network for the transmission of hydrogen from Portugal, Spain and France to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

For the upstream French hydrogen transmission project RHYn, HYD-N-969, GRTgaz has calculated a capacity of 12 GWh per day for the PCI application, which will be shipped via the new cross-border IP at Freiburg. For Freiburg, a capacity of 12 GWh per day was agreed with the German partners for the RHYn Interco project, HYD-N-1096, which is directly connected to the new cross-border IP. The requested PCI RHYn Interco is part of the German hydrogen core network. Therefore, an entry capacity of 0.5 GW was set in Freiburg for the test year 2032.

Austria: Überackern

The planned capacity for hydrogen from Austria to Germany was agreed between the technical experts from Gas Connect Austria and bayernets as part of the applications for the 6th list of Projects of Common European Interest (PCI). The proposed projects H2 Backbone WAG + Penta-West (HYD-N-757) and HyPipe Bavaria – The Hydrogen Hub

(HYD-N-642) serve to create a European hydrogen network for the transmission of hydrogen from North Africa via Italy and Austria to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E as part of the SoutH2 Corridor initiative. In addition, within the scope of the H2EU+Store initiative, the proposed projects also enable the transmission of hydrogen from Ukraine via Slovakia and Austria to the Überackern cross-border IP.

For the upstream Austrian hydrogen transmission project H2 Backbone WAG + Penta-West, Gas Connect Austria has determined and agreed an entry capacity of 150 GWh per day for the PCI application with the partners of the initiatives for the German-Austrian cross-border IP Überackern. The proposed PCI HyPipe Bavaria – The Hydrogen Hub is part of the German hydrogen core network. An entry capacity of 6.25 GWh/h was therefore assumed at the Überackern cross-border IP for the test year 2032.

Czech Republic: Waidhaus

The planned entry capacity for hydrogen from the Czech Republic to Germany was agreed between the technical experts from GRTgaz Deutschland, Net4gas and Open Grid Europe as part of the applications for the 6th list of Projects of Common European Interest (PCI). The proposed Central European Hydrogen Corridor and H2ercules projects serve to create a European hydrogen network for the transmission of hydrogen from Ukraine via Slovakia and the Czech Republic and from North Africa via Italy, Austria, Slovakia and the Czech Republic to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

For the upstream Czech hydrogen transmission project Central European Hydrogen Corridor (CZ part), HYD-N-990, Net4gas has calculated a capacity of 144 GWh per day at the Waidhaus cross-border IP for the PCI application. This capacity was agreed with the German partners for the H2ercules Network South project, HYD-N-1052, which is directly adjacent to the cross-border IP. The proposed PCI H2ercules is part of the German hydrogen core network. An entry capacity of 6 GW was therefore set in Waidhaus for the test year 2032.

Czech Republic: Deutschneudorf

The planned capacity for hydrogen from Germany to the Czech Republic and the return feed-in from the Czech Republic to Germany in Waidhaus was agreed between Net4Gas, GASCADE and Open Grid Europe as part of the applications for the 6th list of Projects of Common European Interest (PCI). The submitted projects Flow East, CGHI and H2ercules South serve to create a European hydrogen network for the transmission of hydrogen, initially from Denmark and in later years from Sweden and Finland to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E. In addition, the PCI projects in Deutschneudorf also offer the possibility of feeding hydrogen from the Czech Republic into the German hydrogen network.

Net4Gas has calculated a capacity of 144 GWh per day for the Czech hydrogen transmission project CGHI for the PCI application. A capacity of 144 GWh per day was therefore assumed for Deutschneudorf, as the capacity is limited by the proposed PCI CGHI. The proposed PCI Flow East is part of the German hydrogen core network. Therefore, an entry and exit capacity of 6 GW was assumed in Deutschneudorf for the test year 2032.

Poland: Oder-Spree, Uckermark

As part of the determination of the hydrogen core network, two different cross-border IPs on the state border with Poland were considered: in the Oder/Spree district near the town of Eisenhüttenstadt and in the Uckermark district near the town of Schwedt.

The planned capacity for hydrogen from Poland to Germany for both cross-border IPs was discussed between GAZ-SYSTEM and ONTRAS as part of the applications for the 6th list of Projects of Common European Interest (PCI). The proposed projects Polish Hydrogen Backbone Infrastructure HYD-N-983 (connection to the Polish hydrogen network near Schwedt) and Nordic-Baltic Hydrogen Corridor HYD-N-1310 (connection to the Polish hydrogen network near Eisenhüttenstadt) serve to establish a European hydrogen network for the transmission of hydrogen directly from Poland and from the North-East Europe region via the Baltic States and Poland to Germany within the meaning of Section 28r (4)(4)(b) EnWG-E.

As part of the Polish hydrogen transmission project Polish Hydrogen Backbone Infrastructure of GAZ-SYSTEM, there are plans for feed-in of hydrogen in West Pomerania along with its export to Germany via a connection in Schwedt. The further development of the project was agreed in a joint MoU between the network operators GAZSYSTEM and ONTRAS with the H2 producer. A capacity of 0.8 GWh per hour was initially set as realistic for the cross-border IP near Schwedt for the year 2032.

For the Nordic-Baltic Hydrogen Corridor hydrogen transmission project, GAZ-SYSTEM and ONTRAS have each calculated a capacity of 200 GWh per day for the PCI application. For the cross-border IP near Eisenhüttenstadt, a capacity of 48 GWh per day was estimated as realistic for the year 2032. An entry capacity of 2 GW was therefore assumed for this cross-border IP for the test year 2032.

Annexes

Annex 1: Project overview for the hydrogen core network scenario

The scenario for the hydrogen core network was described in section 2. Annex 1, which is published on the FNB Gas website, lists the hydrogen projects that were taken into account in the scenario for the hydrogen core network.

Annex 2: Reportet linesfrom other potential hydrogen network operators

The transmission system operators have given the operators of gas distribution networks, the operators of hydrogen networks, and the operators of other pipelines the opportunity to comment on the planning status document from July 12, 2023, to July 28, 2023, and in this context have called for the notification of pipeline infrastructure for the hydrogen core network.

In Annex 2, the transmission system operators present the pipeline notifications received for the hydrogen core network and show which pipelines were included in the hydrogen core network and which were not. This decision is justified in Annex 2. Accordingly, this annex shows which pipelines of other potential hydrogen network operators the transmission system operators propose for consideration in the hydrogen core network.

Annex 3: List of measures of the transmission system operators

The measures identified for the hydrogen core network are described in detail in Annex 3.

The transmission system operators set out the technical parameters of their measures for the hydrogen core network in this annex. According to Section 28r (4) EnWG-E, a hydrogen network infrastructure must meet certain requirements in order to be an approvable part of the hydrogen core network. To demonstrate these requirements, the transmission system operators, in consultation with the BNetzA, have included corresponding columns in this annex in which the hydrogen core network measures are assigned to the statutory requirements, in particular with regard to Section 28r (4) sentence 4 EnWG-E.

The transmission system operators point out that the list of measures is to be understood as including accessories and ancillary facilities necessary for operation.

The transmission system operators also point out that it is only possible to clearly assign the individual measures to the legal requirements in a few exceptional cases. The hydrogen core network will be built resiliently and should enable free allocability between feed-in and feed-out. To this end, the transmission system operators have modelled several load cases for the hydrogen core network, as described in section 4.4, in order to test the hydrogen entry and exit capacities for free allocability. The load flows within the hydrogen core network are therefore only clear for a few pipeline sections. Moreover, it must be possible to connect every feed-in point to every exit point for balancing purposes, which will contribute directly to the decarbonization of all branches of industry. This also applies to the same extent to the pipelines and pipeline sections that connect these feed-in points. A "transmission pipeline", which is located in the middle of the hydrogen core network, is also necessary for a large-scale supply and therefore fulfils a large number of the requirements specified in the law. A more specific allocation, for example to individual customer groups, is only possible for a "regional pipeline", which is located at the edge of the hydrogen core network and does not connect any feed-in points.

A clear allocation of the measures to the legal requirements therefore brings uncertainties. In particular, the allocation of measures in the hydrogen core network to the specific hydrogen feed-in and feed-out projects (see Annex 1) is not possible for the reasons mentioned.

Annex 4: Detailed map of the hydrogen core network

Annex 4 provides a detailed cartographic representation of the pipelines and compressors of the transmission system operators considered as a result of the modelling of the hydrogen core network as well as the pipelines of the other potential hydrogen network operators considered. The map has a high resolution and contains a search function for locating the individual pipeline sections and the line compressors in Achim and Forchheim using their ID numbers from Annexes 2 and 3.

Glossary

Para.	Paragraph
EEZ	Exclusive Economic Zone
bar(g)	Pressure referred to sea level
BDEW	German Association of Energy and Water Industries (Bundesverband der Energie- und Wasserwirtschaft e.V.)
BKAmt	Federal Chancellery (Bundeskanzleramt)
BMF	Federal Ministry of Finance (Bundesministerium der Finanzen)
BMW	Federal Ministry of Economics and Climate Protection (Bundesministerium für Wirtschaft und Klimaschutz)
BNetzA	Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen)
CEF	Connecting Europe Facility
CO2	Carbon dioxide
e	electric
EnWG	Energy Industry Act
EnWG-E	Draft Energy Industry Act (Cabinet decision of May 24, 2023)
EC	European Commission
TSO	Transmission system operator
FNB Gas	Association of German Transmission System Operators (Vereinigung der Fernleitungsnetzbetreiber Gas e.V.)
GPRM	Gas pressure regulating and metering stations
IP	Interconnection point
GW	Gigawatt
GWh	Gigawatt hour
IPCEI	Important Project of Common European Interest
CHP	Combined heat and power generation
MW	Megawatt
NDP	Network development plan
NHS	National hydrogen strategy
PCI	Projects of Common Interest
PMI	Projects of Mutual Interest
SEN	Other North Sea energy production area, area earmarked for the production of hydrogen from wind power
SLP	Standard load profile

th	Thermal
TWh	Terawatt hour
DSO	Distribution system operator
HPD	(Market survey) Hydrogen production and demand *("Marktabfrage – Wasserstoff Erzeugung und Bedarf" (WEB))*
No.	Number

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