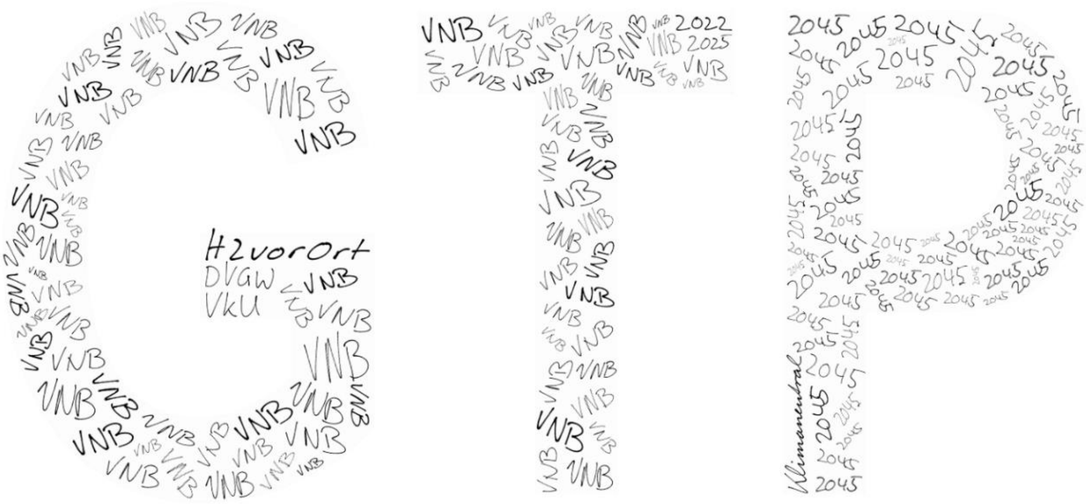
The Gas distribution Transformation Plan



Making hydrogen available to everyone via the gas distribution networks

GUIDELINE
2022

Data feedback
until 30/6/2022 | gtp-h2vorort@dvgw.de

This document was drafted through the H2vorOrt Initiative within the DVGW in cooperation with the VKU (Verband kommunaler Unternehmen – German Association of Local Public Utilities). The core work took place within the ‘Working group on the Gas distribution Transformation Plan’.

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Guidelines on the Gas distribution Transformation Plan 2022

Contents

Introduction

The amendment of the Federal Climate Change Act means that the German government has tightened climate protection regulations and made the goal of greenhouse gas neutrality by 2045 legally binding. Given the energy transition and the ambitious climate targets the federal government has set itself, alternative options are needed to the fossil-based energy sources currently being used, and the search is on for efficient energy storage technologies. As an energy source, hydrogen is vitally important for achieving this objective and related climate protection goals. This fuel gas has enormous potential in terms of climate protection because no harmful greenhouse gases are generated by burning it. Hydrogen can also be used to store energy and can be utilized across many sectors, including for heat supply in buildings.

From the feed-in point, to the distribution network, and through to the interface with network customers, existing gas infrastructure offers huge potential without needing major adjustments. Potential modifications required for hydrogen in particular, must be considered separately. Its impacts on pipeline materials, components and systems (especially gas pressure regulation and measuring systems) specifically require precise testing/evaluation for transport suitability and hydrogen distribution (H_2-readiness). This is the basis for converting pipelines from gas to hydrogen, thus transforming a gas network area. In addition, the generation and import capacities needed for hydrogen must be created and used in parallel so that the needs of the heating sector as well as those of industry and business can be met.

In the 'H_2vorOrt' project, more than 45 gas supply companies, in close cooperation with the DVGW, have developed a transformation path (Gas distribution Transformation Plan / GTP) for gas distribution system operators (DSOs) in order to practically organize the regional, secure supply of climate-neutral gases. The Gas distribution Transformation Plan therefore constitutes the central and standardized planning instrument for the decarbonization of the gas distribution networks.

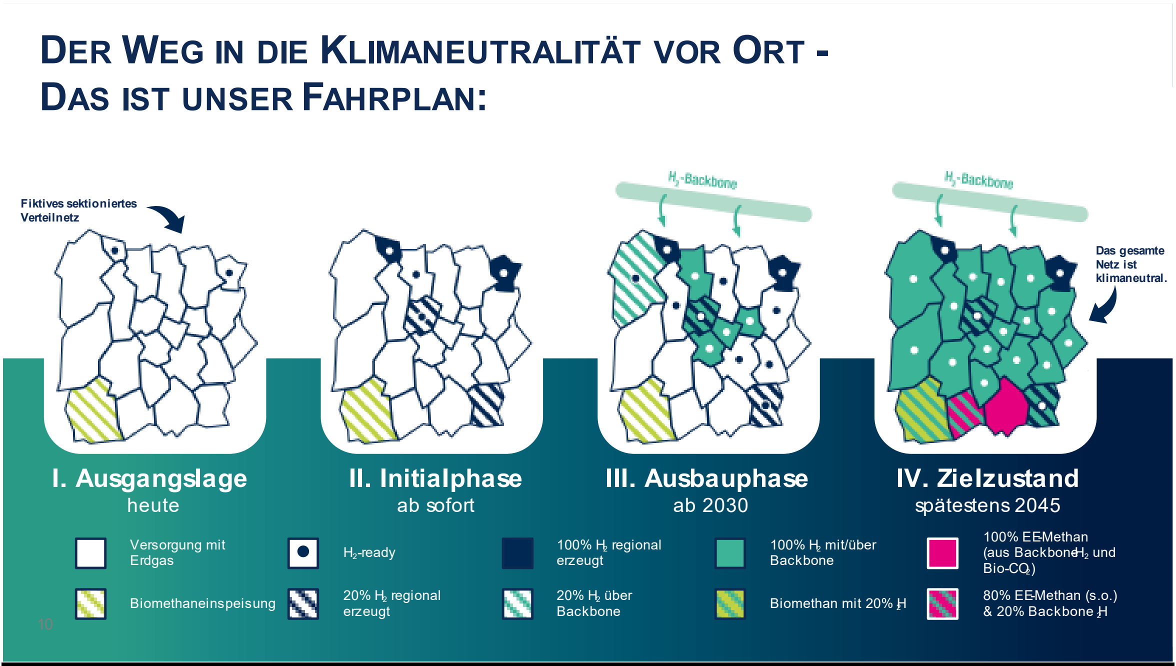
These guidelines summarize the steps involved in developing the GTP through the individual DSOs (up to section 10). More detailed background information is available in the appendix (section **Fehler! Verweisquelle konnte nicht gefunden werden.**). Based on the individual plans of the gas distribution system operators, an overall, nationwide GTP will also be developed by H2vorOrt by means of standardized feedback (section 9). This will assist in the coherent transformation of the German gas infrastructure. The GTP will be produced annually, with the analysis deepening year on year.

To provide the best possible support for Germany's transformation to climate neutrality, the gas distribution network operators need to be as ambitious as possible when it comes to their own transformations. The GTP will help to translate a high level of ambition to operational practice through cooperation with on the one hand, customers and local producers, and on the other, upstream grid operators – representing essentially, the hydrogen backbone of the TSOs.

1 Area of application

These guidelines are an aid to developing a pathway for transforming a gas distribution network from the status quo to climate neutrality using a uniform approach within the framework of legal objectives. For this purpose, subnetwork/ network area planning within the gas distribution networks is set out, with each area operating with 100 volume percent hydrogen, 100 volume percent climate-neutral methane or a combination of these in the form of blended gas (corresponding to the 2nd and 5th gas families according to DVGW G 260 (A)). Gas installations on the private customer side (TRGI [Technische Regel für Gasinstallationen] – Technical guidelines for gas installations) are not covered by the GTP – only items owned by the distribution system operators.

Figure 1 shows an example of a transformation plan for a fictitious gas distribution network.



The path to local climate neutrality -
This is our roadmap:

Fictitious sectioned distribution network		**H_2 backbone**	**H_2 backbone**
			The entire network is climate-neutral
I. Starting position today	**II. Initial phase from now**	**III. Expansion phase from 2030**	**IV. Target scenario by 2045 at the latest**

Supply with natural gas	**H_2 ready**	**100% H_2 regionally produced**	**100% H_2 with/via backbone**	**100% RE methane (from backbone H_2 and bio-CO2)**
Biomethane feed-in	**20% H_2 regionally produced**	**20% H_2 via backbone**	**Biomethane with 20% H_2**	**80% RE methane (see above) and 20% backbone H_2**

Figure 1: The path to local climate neutrality

2 Applicable documents

The following documents are required for the use of this document. In the case of dated references, only the referenced edition applies. Users are asked however, to apply the respective latest editions of the normative documents mentioned below. For undated references, the latest edition of the document referenced applies (including all amendments).

2.1 DVGW Set of Rules

DVGW G 221 (M), Guidelines for the Application of the DVGW Set of Rules to the pipeline supply of hydrogenous gases and hydrogen to the general public (*Leitfaden zur Anwendung des DVGW-Regelwerks auf die leitungsgebundene Versorgung der Allgemeinheit mit wasserstoffhaltigen Gasen und Wasserstoff)*

DVGW G 260 (A), Gas quality (*Gasbeschaffenheit)*

DVGW G 402 (A), Network and damage statistics – Collection and evaluation of data for developing maintenance strategies for gas distribution networks (*Netz- und Schadenstatistik - Erfassung und Auswertung von Daten zum Aufbau von Instandhaltungsstrategien für Gasverteilungsnetze)*

DVGW G 407 (M) *Conversion of gas lines made of steel pipes up to 16 bar operating pressure for the distribution of hydrogenous*, *methane-rich gases and hydrogen* (in preparation) *(Umstellung von Gasleitungen aus Stahlrohren bis 16 bar Betriebsdruck für die Verteilung von wasserstoffhaltigen methanreichen Gasen und Wasserstoff*)

DVGW G 408 (M) *Conversion of gas lines made of plastic pipes up to 16 bar operating pressure for the distribution of hydrogenous, methane-rich gases and hydrogen* (in preparation) *(Umstellung von Gasleitungen aus Kunststoffrohren bis 16 bar Betriebsdruck für die Verteilung von wasserstoffhaltigen methanreichen Gasen und Wasserstoff*)

DVGW G 410 (A), Registration of asset inventory and incident data of gas infrastructure (*Bestands- und Ereignisdatenerfassung Gas)*

DVGW G 463 (A), *High-pressure gas steel pipelines for a design pressure of more than 16 bar; design and construction (Gashochdruckleitungen aus Stahlrohren für einen Auslegungsdruck von mehr als 16 bar; Planung und Errichtung)*

DVGW G 472 (A), Gas lines made of plastic pipes up to 16 bar operating pressure; construction (*Gasleitungen aus Kunststoffrohren bis 16 bar Betriebsdruck; Errichtung)*

2.2 Laws and regulations

Energy Industry Act (Energiewirtschaftsgesetz [EnWG])

Gas Network Access Ordinance (Gasnetzzugangsverordnung [GasNZV])

2.3 Other technical rules or other publications

Gas Cooperation Agreement (Kooperationsvereinbarung Gas [KoV])

2.4 Accompanying documents

Download at: **www.h2vorort.de**

Feedback form: GTP_2022_Netzbetreibernummer.xlsx

https://www.dvgw.de/medien/dvgw/verein/energiewende/GTP_2022_Netzbetreibernummer.xlsx

Feedback form on example from section 11: (Example)_GTP_2022_9870105555555.xlsx

https://www.dvgw.de/medien/dvgw/verein/energiewende/_Beispiel__GTP_2022_9870105555555.xlsx

Optional template RLM- and GHD-SLP customers: GTP_2022_Kundenanalyse_Template_intern.xlsx

https://www.dvgw.de/medien/dvgw/verein/energiewende/GTP_2022_Kundenanalyse_Template_intern.xlsx

3 Terms and abbreviations

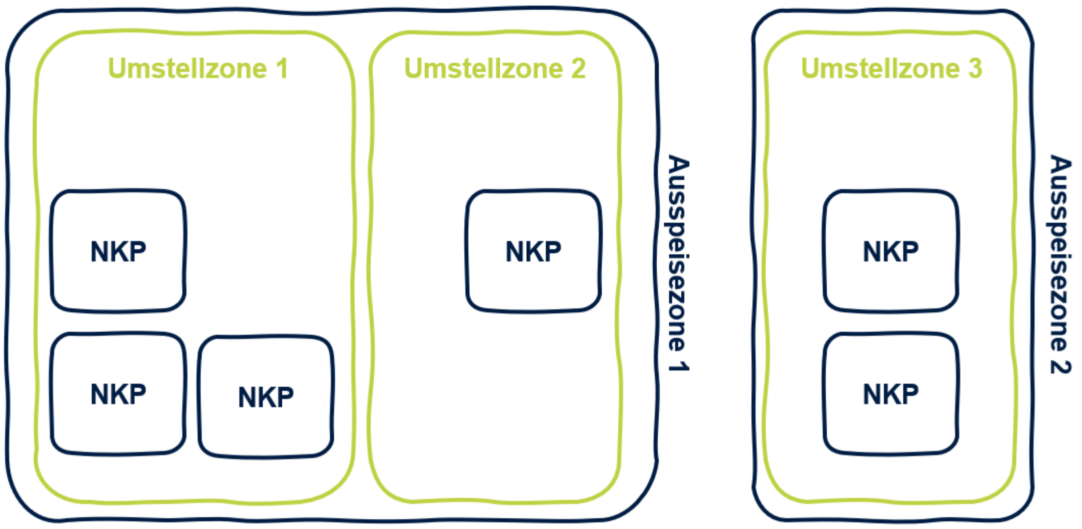
H_2 ready, H_2-readiness: Within the context of the GTP, H_2-readiness describes determining the long-term suitability and usability of energy system components (in terms of the EnWG (German Energy Industry Act), i.e., components, pipelines, assemblies, system parts, etc.) for hydrogen operation (5^{th} gas family) according to the DVGW work sheet G 260. Operation with methane-rich gases of the 2^{nd} family with or without hydrogen as an additional gas should continue to be possible. In the context of the GTP, the term is broadened to apply to network sections and networks.

DGO, UGO: Downstream grid operator (DGO) – in German: Nachgelagerter Netzbetreiber (NgNB) / Upstream grid operator (UGO) – in German: Vorgelagerter Netzbetreiber (VgNB)

NUTS (*French: Nomenclature des unités territoriales statistiques*)**:** refers to a hierarchical system for the clear identification and classification of spatial reference units of official statistics in the member states of the European Union. NUTS-3 therefore refers to the 401 districts and non-district cities, or in Baden-Württemberg, city districts.

Subnetwork: A subnetwork of a distribution network operator (DSO) is an independent gas network in terms of network hydraulics.

Conversion zone: Conversion zones are logical and (potentially) separate (in terms of network hydraulics) subdivisions of the network for converting to hydrogen or other climate-neutral gases. They must be supplied with the same gas (H_2 or CH_4) by the upstream grid operator for network topological reasons or are not network-topologically separable (sectionable) on the DSO side. This may coincide with the exit zones or network interconnection points from the internal order. Exit zones comprising of several different pipelines of the upstream grid operator (or loop pipelines) can be divided into several conversion zones.



Conversion zone 1		Conversion zone 2	Exit zone 1	Conversion zone 3	Exit zone 2
NIP		**NIP**		**NIP**	

NIP	**NIP**			**NIP**	

Figure 2: An exit zone can comprise of one or more conversion zones. A conversion zone contains one or more network interconnection points (NIPs) to the upstream grid operator/ hydrogen source

4 Framework conditions for the transformation planning

4.1 Market framework conditions

a) It is assumed that policy will create the framework conditions that facilitate the progressive decarbonization of gas consumption – reflecting the federal government's climate objectives. This is in line with the call of H2vorOrt to have a green gas target, along with an implementation pathway like for example, a rising quota system.

b) The GTP assumes that H_2-readiness measures will soon be recognized under the gas network regulation.

c) Climate objectives are decisive for transformation planning, not current theories on quantity provision of climate-neutral gases. To be able to realize this reduction potential, the necessary quantities of climate-neutral gases must be made available. We assume that the network development plan will fully ensure a timely and demand-oriented expansion of supply infrastructure for climate-neutral gases, a significant portion of which will be generated in a decentralized way. We trust that policymakers will create the framework conditions needed for a corresponding market ramp-up in terms of production.

4.2 Technical framework conditions

a) The entire distribution network should be able to transport climate-neutral gases by 2040 at the latest. Networks for the long-term transport of 100 volume percent H_2 must therefore be 100 percent H_2 ready by 2040 at the latest.

b) The variety of climate-neutral gases (hydrogen, biomethane, SNG, etc.) should be optimally exploited in line with targets. Guaranteed decentralized generation should be incorporated.

c) Irrespective of scheduling, maintenance activities will already be carried out within the scope of H_2-readiness.

d) The DVGW will ensure that the rules on 20 volume percent/ 100 volume percent H_2 are in place in a timely fashion.

e) Current political will indicates that new CHP plants or gas power plants must be built to be H_2 ready. It is recommended that this requirement be applied as broadly as possible, also to new RLM customers/ applications or that existing customers are informed sufficiently early about the necessity of H_2-readiness.

4.3 Climate policy framework conditions

a) Regional climate objectives and requirements are the target parameters (municipal heat planning). The GTP functions here as a bridge to convey the climate protection requirements of the municipalities to the TSOs as well as to the federal state and national political levels. Achieving sectoral targets will be supported at the municipal level (bottom-up analyses of the local authorities).

b) In the dialogue on municipal heat planning, which is to be introduced nationwide according to the coalition agreement, it should be noted that the (already existing) assets in gas infrastructures could be usefully complemented by heating networks to facilitate an optimal macroeconomic solution for the accelerated, heating transformation on the local level.

c) The consolidated conversion plan across all DSOs must add up to fulfil the German climate target (Climate Change Act). Spatial and temporal development plans will be accounted for overall in line with the target.

- 65 percent less CO_2 compared to 1990 by 2030
- 88 percent less CO_2 compared to 1990 by 2040
- Climate neutrality by 2045

4.4 Other framework conditions

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

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

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

5 Overview of the analysis paths of the individual plans

5.1 The four analysis paths

Following the framework conditions for the transformation mentioned in the previous section, the next three sections represent the core of the 'Guidelines for establishment of a Gas distribution Transformation Plan (GTP)'. These comprise a total of four analysis paths which must be developed by the DSOs in preparing the GTP:

- Feed-in analysis (section 6)
- Capacity analysis (section 7)
- Customer analysis (section 7)
- Technical analysis (section 8)

With the start of the **feed-in analysis**, the DSO looks at the secured feed-in of biomethane, SNG or hydrogen into its existing gas network. If for example, the DSO only has natural gas feed-ins in its gas network (in the status quo), the analysis is already complete with the result: '100 percent natural gas feed-in'. In all other cases, further analyses are required with regard to feed-in suitability and gas quality.

Because the content of the **capacity and customer analyses** are closely interlinked, they are placed together in one section. This simplifies the issue for the DSO and avoids unnecessary duplication.

The aim of the capacity analysis to classify the gas network into conversion zones which, together with other analyses, yields a basis for an indicative conversion sequence for the DSO transformation path. A bottom-up evaluation of the conversion zones is combined with a top-down validation through discussions with the upstream grid operator/ transmission system operator for this purpose. Both processes are interdependent and will be conducted on an iterative basis in practice.

A major focus is network customers and municipalities, who provide crucial input and thereby a framework for the conversion zones and their order of conversion. The guidelines provide the DSO with explanations on a wide range of issues, templates for structuring their network customers and explanatory examples, in the knowledge that the DSO itself knows its own gas network, upstream grid operators, network customers and municipality the best. In this regard, the DSO can potentially incorporate its own particular characteristics into these two analysis paths, thereby improving the quality of its GTP.

The DSO formulates its requirements as a result for the H_2 backbone of the transmission system operators (directly or indirectly in terms of its upstream DSO). Specifically, how much capacity it needs at which network interconnection point or exit zone at what specific time. As a further component of its GTP, it uses assumptions about its network customers in the framework of the internal customer analysis. These then have an influence on the decisions for the design and prioritization of the conversion zones.

The **technical analysis** completes the four analysis paths. It includes the analysis of the network components, examining a sectioning of the conversion zones into subnetworks and the network hydraulic analysis. The planning of H_2-readiness should be complete by 2025, in line with the commitment and recommendation of H2vorOrt.

Consequently, the analysis steps of the four analysis paths are not to be conducted immediately or fully by the DSO. Taking a pragmatic and realistic approach, the individual analysis paths are to be distributed along a so-called optimization development scale between 2022 and 2025. An overview can be found in section 5.2. This provides the DSO with orientation and classification – 'faster' is allowed, 'slower' would be critical - in order to keep the transformation path feasible, working towards the climate targets and enabling consolidation to an overall, nationwide GTP.

As a result, the DSO maintains its GTP for the entire transformation of its gas network to climate neutrality for all network customers in the identified conversion zones. With the integration of the individual GTPs into a nationwide GTP of DSOs, the DSO also gains a classification of its GTP in the overall context and thus ultimately an additional strong 'argument' on its path to the decarbonized era by 2045 at the latest.

5.2 Optimization development of individual planning

Optimization development, GTP

Feed-in analysis	2022 • Status quo • (Planning calorific value tracking)	2023 • Update • Feed-in suitability	2024-2025 • Update
Capacity analysis	• Alignment/ Requirement TSO • Point in time	• Update	• Update

	• Quantities/ Capacities • NIP/ Conversion zone		
Customer analysis	Internal customer analysis (Customer discussions) (Discussion with municipalities)	Customer discussions Discussions with municipalities	Customer discussions (update) Discussions with municipalities (update)
Technical analysis	Pipeline material 1st network hydraulic analysis	Pipeline components Plant components 2nd network hydraulic analysis	Upgrade plan

Figure 3: Optimization development of the GTP

With its increasing scope and accuracy, the GTP is to develop into a reliable plan over the coming years, which should be completed by 2025. Figure 3 shows an indicative development of the optimization development of the GTP, which maps out the plan’s progress. It will be examined and amended where necessary in the framework of revising the guidelines on the annual GTP compilation. The aim here is to increase optimization every year.

5.3 Cascading of results from downstream grid operators

GTP planning should be prepared by all distribution network operators. It is particularly important here in the case of downstream grid operators that there is continuous coordination with the respective upstream DSO early on, as the results of the downstream GTP are fed into the upstream grid operator's GTP (especially 7.1.3). Conversely, decarbonization options for the downstream grid operators are based on decarbonized gas being made available by the upstream grid operators (cf. 7.2). This is similar to the reporting cascade of internal ordering from the Gas Cooperation Agreement (Kooperationsvereinbarung Gas), however without involving the TSOs for feedback.

6 Feed-in analysis

6.1 Status quo

The feed-in of biomethane, SNG or hydrogen also may have an impact on the conversion of the local subnetwork. Therefore, a list of the network feed-ins of decentrally generated gases is required. Only guaranteed feed-ins or the latest network connection requests are to be taken into account for this analysis which is relevant to network planning, not studies on the potential of biogas or hydrogen generation.

The following questions must be answered:

- In which subnetworks are such feed-ins found?
- What gas from which gas family is fed in by the producers of the gas?
- Condition of the plant, RED-II capability[1] and economic viability[2]: How long can the feed-in operation be expected to continue or from when is a feed-in planned?

On this basis, subnetworks will be identified where a conversion to H_2 must be examined separately in the case of an existing biomethane feed-in. Potential solutions will be developed for these cases as part of the technical analysis.

Equally, there are areas to be identified that could be converted early to local, climate-neutral, network supply because of existing local feed-in or production (biomethane or locally generated hydrogen).

6.2 Feed-in suitability

Not the subject of GTP 2022: To make a plausible evaluation about which points in the network are particularly suitable for hydrogen feed-in, detailed knowledge is needed about the connected customers

[1] This refers to e.g., share of liquid manure in the biogas production. RED II = Renewable Energy Directive II.

[2] In each case, to the extent that is known

as well as the relevant measuring technology in the network, therefore it is not a subject of GTP 2022. This knowledge should be rapidly expanded, however. See also section 12.1.

6.3 Gas quality and calorific value tracking

One of the original tasks of the network operator is to reliably provide perfect gas quality in accordance with the DVGW Set of Rules to its end customers – particularly industrial customers with more complex quality requirements. That is why a constant percentage admixture, leading to a near constant gas quality in the network, is easier to handle. Fluctuating admixtures require continuous monitoring of the gas quality via live network management (Wobbe Index range with calorific value tracking) and managing it in such a way as to maintain the contractually agreed value limits at every exit zone and network connection point. The network operator must establish suitable measurement and control procedures (telecontrol, sensors etc.). This way on the one hand, sensitive RLM (real-time metered) customers with critical production processes can be protected and on the other, internal processes such as energy quantity-based billing can be guaranteed.

Gathering the following characteristic parameters are recommended for monitoring gas quality:

- H_2 concentration [vol-%]
- Calorific value of the gas mixture [kWh/m^3]
- Wobbe Index [kWh/m^3]
- Standard density [kg/m^3]
- Proportion of hydrocarbons [mol-%]

In so far as the dynamic feed-in situation requires it, the network operator continuously records these parameters via measurement and telecontrol technology. It is especially conceivable that recording takes place downstream of feed-in points or admixture stations as well as upstream from sensitive RLM and SLP customers. Should the above parameters stray outside the target corridors defined for that network section, this must be combatted by blending gas, for example. Alternatively, sensitive customers can also potentially be protected through membranes that separate hydrogen and methane.

The DVGW Set of Rules on this is currently being developed.

Note: Experience with calorific value tracking systems for biomethane feed-in from ongoing operations can be used as a basis for expanding this to H_2 tracking.

7 Capacity and customer analysis

The aim of capacity analysis is an initial, capacity-based classification of the network into conversion zones, that together with the other GTP analyses, act as a basis for an indicative conversion sequence (subnetworks) and ultimately for the conversion dates for future 100 percent climate-neutral supply. Should, in addition to 100 volume percent H_2, interim or final scenarios with admixture be envisaged, these are then to be taken into consideration accordingly for each conversion zone.

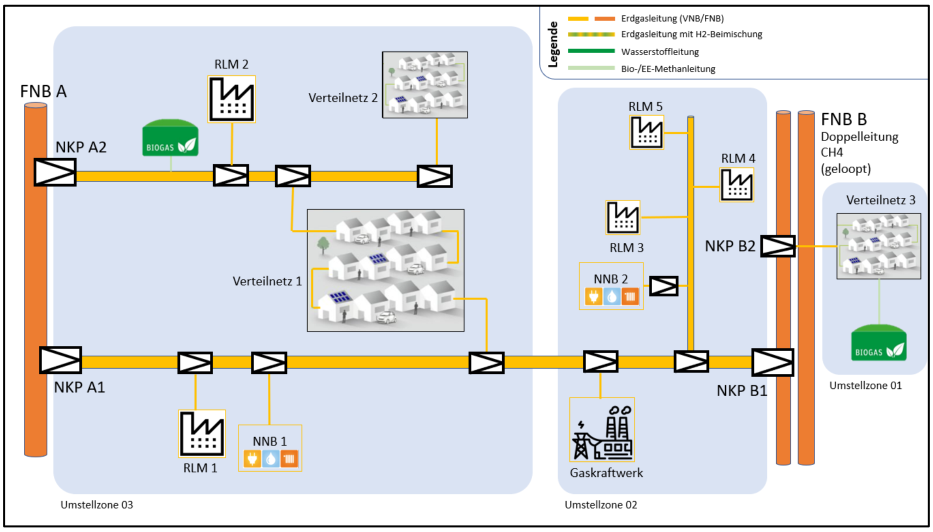
For this purpose, a bottom-up evaluation of the conversion zones will be combined with a top-down evaluation through discussions with the upstream grid operator/ TSO. Both processes are interdependent and will be iteratively conducted in practice.

7.1 Bottom-up evaluation

7.1.1 Starting point: Determining capacity and network topology

As an initial step, the DSO examines the output (kWh/a) and capacity (kWh/h) required for its entire network or subnetwork, if applicable, at the network interconnection point(s) to the upstream grid operator. Capacity and output are known from measuring equipment at the network interconnection points. These form the basis for the quantities that are to be replaced by climate-neutral gases (minus any decentrally-generated quantities).

Based on the network interconnection points, as well as their own and upstream network topology, an initial subclassification into conversion zones is made. They may be identical with the exit zones from internal ordering. This first hypothesis regarding conversion zones will be further developed as a result of discussions with the upstream grid operators on the one hand, and through customer analysis and technical analyses on the other. The goal is to obtain a partitioning (sectioning) of their own network which assists in geographically determining a sequence for conversion to hydrogen or other green gases. Both conditions and requirements of the upstream operator and the customers should be represented as much as possible.



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'UGO' statt ‚NBB‘
'Conversion zone' statt 'Umstellzone'
'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Figure 4: Example of division in conversion zones (see example)

Optional: In addition, a simplified network design will be created for every subnetwork with all network interconnection points to the upstream and downstream network and the major pipeline sections, in which the conversion zones will be represented (input for step 2).

Note:

- Should you lack detailed measurements at your NIPs, an estimate that provides values relevant for planning, at least at the level of the conversion zones, is also acceptable.
- If necessary, quantity/capacity will be adapted on the basis of the long-term prognosis (in accordance with the Gas Cooperation Agreement), taking premise 4 into account.

7.1.2 Determining and evaluating customer groups

After the quantities to be converted for the entire network or subnetwork in step 1 have been determined and following subdivision into conversion zones, the customers to be converted will be allocated to different customer groups in this step. Individual customer groups will then be examined more closely in the framework of a detailed customer analysis. The customer groups represent a classification from which a conversion sequence cannot necessarily be derived, because for the most part, DSO networks are mainly interconnected and apply across customer groups. Customer needs and potentials can nevertheless, in combination with other factors, influence the order of conversion.

The following groups have been identified:

[1] Customers with special decarbonization specifications (taxonomy, etc.). Individual, large customers have (EU) legally prescribed, strategic or contract- or market-dependent decarbonization guidelines. These customers can increase the conversion priority of the subnetwork. If necessary, these customers would have to be converted separately (separate interim supply with H_2). In particular, CHP should be taken into consideration.
For details see 12.2.

[2] RLM customers not categorized under [1] who have a high decarbonization potential (large output/capacity)
Individual large customers may provide particular motivation to achieve (interim) decarbonization targets. Additional designations (see below) are to be noted.

[3] Downstream grid operators with their own GTP (see below, 0)

[4] SLP customers and remaining RLM customers by analogy to converting the market area
For the conversion of SLP customers, an industry-wide approach similar to the market area conversion[3] will be developed, a process that can be mass produced in order to reach the decarbonization targets in this sector as well. A specific procedure for H_2 market area conversion is

[3] 1. Note: The conversion zones do not correspond to the detailed conversion districts of the market area conversion with their necessary small scale, but are designed for annual accuracy and the corresponding sizing.

currently being prepared in the DVGW technical committee: ‘Domestic and industrial gas applications’.

[5] Customers who do not currently have an active grid connection but have expressed interest in hydrogen.

The following designations are to be attributed to the customers concerned where applicable:

[A] Customers with technical criticality (production processes, etc.)
Individual customers will have specific requirements in terms of gas quality (possibly also customers without a high decarbonization potential). These customers can also influence the conversion priority of a conversion zone. Here, a distinction must be made between admixture and 100 volume percent H_2. For customers who fundamentally, cannot tolerate > 2 volume percent H_2, a strategy (e.g., alternative supply) or a technical solution (e.g., methane) must be developed where necessary. For details see 12.2.2.

[B] Customers with other requirements or circumstances
Customers who are known to potentially decarbonize through electrification, or areas where known alternative heating solutions (e.g., district heating) are planned as part of integrated supply, as well as other relevant circumstances with an impact on planning.

These customer groups are to be stored with number, output and capacity data, and for the groups [1] – [3] and [5], also on an individual customer basis. Customers with the designation [A, B] must be adequately described. This data forms the basis for detailed customer analysis and together with the feed-in analysis, serves as a basis for detailing the conversion zones and their prioritization. It is especially worth identifying here customers who require moving the date of the conversion of the conversion zone (either sooner or later) or who must be converted separately.

As part of integrated supply planning, there may also be areas which are no longer to be directly supplied with gaseous energy (e.g., group 4 with designation [B]). These areas are to be designated as separate (conversion) zones.

Optional: The customer from groups [1] – [4] as well as the feed-ins will now be located in the conversion zones in the simplified network design from step 1. Customer groups and feed-ins will be optically distinguishable.

On the basis of these steps, the DSO can recognize whether there is a clustering in the network design of certain customer groups in certain conversion zones. In addition, it will emerge where there is a customer priority because of an identifiable build-up of customers in category [1] and, where there may be a strongly intensified decarbonization potential because of [1] and [2] clusters. From locating [1] – [5] including [A, B] and the associated supporting and hindering factors, an initial, indicative prioritization emerges (see example in section 10). Network structures may also become apparent which suggest the individual conversion zones. This must be examined in the framework of technical analysis (section 8).

Excursus for downstream grid operators: These steps with capacity analysis, network customer analysis and conversion zones must be carried out by all downstream grid operators. They will signal their needs to their respective upstream grid operator. To facilitate this, early cooperation in this process is important (see also 0,7.2). The rules of internal ordering from the Gas Cooperation Agreement (KoV) apply accordingly.

For assistance: See attached Excel template for recording RLM- and GHD-SLP customers.

7.1.3 Development over the years: Target value analysis

With the results from step 1 and step 2, now indicative conversion dates are to be determined in step 3. The overarching decarbonization targets (cf. 4.3) and strategic corporate climate goals of the DSO should also be taken into account.

The goal is a year-by-year sequence of conversion zones based on the current state of knowledge of the distribution network operator. This will be further developed in subsequent years. Aspects from technical analysis (sectioning) will be taken into account (see also example in section 10) where applicable.

Note:

- Because the H_2 backbone of the TSO (see 7.2 in particular) is a requirement-driven document, it will develop further based on GTP notifications. The high likelihood that the target value analysis could change significantly in subsequent years should not prevent it being developed in the first place. This is an ongoing, iterative process that progressively approaches a Germany-wide, coherent target vision via the GTP iterations:
    - Pipeline conversions on the part of the TSOs could therefore also change in terms of scheduling or scope because of the GTP requests that are gathered. This also applies to upstream DSOs.
    - This has an influence on the internal target value analysis of the GTP creator.

- If there is no detailed analysis on the application of climate goals in the respective company, then the climate targets from 4.3 c) are to be applied directly and in a simplified way to the gas quantities.
- In (conversion) zones with potentially non-gaseous supply, the quantities are to be reduced in the relevant years accordingly.

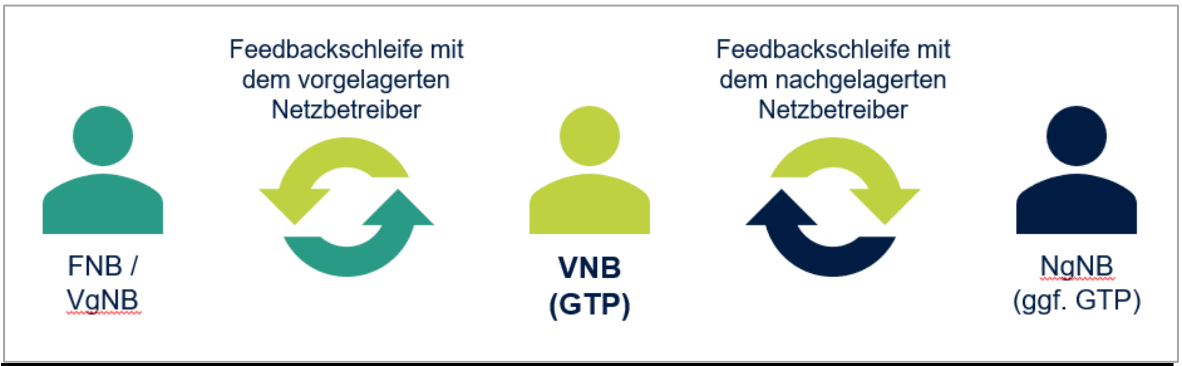
7.2 Top-down validation

7.2.1 Establishing dialogue and obtaining information

As part of its cooperation across network operators with upstream grid operators, in this step the DSO determines at which pipeline sections or network interconnection points and at which point in time and in what capacity and quantity order the upstream grid operator is planning the future hydrogen supply (in the case of a TSO via the H_2-Backbone). In addition, it must be clarified what basic technical framework conditions exists, i.e., how big is the scope that is fundamentally possible (on the basis of e.g., the network topology of the TSO). This means the network operator must provide an initial estimate in terms of timing. This information will be taken into account for bottom-up planning.

As part of this coordination, it must be determined to what extent an admixture provided by the upstream grid operator would be possible as an interim solution.

7.2.2 Iterative feedback loop



TSO/Upstream grid operators	Feedback loops with the upstream grid operator	DSO (GTP)	Feedback loops with the downstream grid operator	Downstream grid operator (GTP where applicable)

Figure 5: **Coordination with the upstream and downstream grid operators**

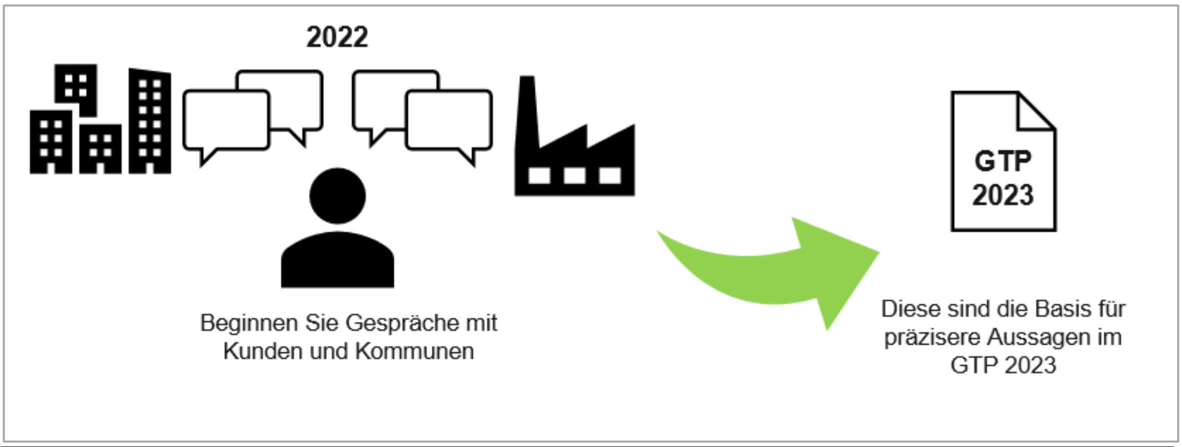
As soon as an initial indicative conversion planning from 7.1 is available or in case of conflict regarding scheduling for step 3 (target value analysis), the upstream grid operators must be consulted to find a solution. The objective must be to bring together the upstream grid operator's plan (e.g., 'visionary hydrogen network') with those of the DSO. Hurdles to implementing the H_2 network at the DSO level must be addressed as part of this step if necessary ('we need hydrogen from 2028, but it's only coming in 2032').

Determining requirements in the GTP must be coordinated with the appropriate processes on the TSO side (green gas query is a current example). Associated queries should be answered in line with the GTP, however in this dialogue with the TSOs, efforts will be made to avoid multiple information requests.

Note: It is assumed that a binding agreement of the TSO may not be achieved in 2022 and that feedback will refer to non-binding scenarios, longer time periods and approximate order sizes in terms of capacity and quantity. In this case, the DSO must make assumptions and communicate them to the TSO. This makes it all the more important that the DSO, based on its existing gas network and its network customers, can tell the TSO where, when and how much capacity or quantity it needs, whether for existing or new network connection points. The 2022 GTP constitutes a first draft and the beginning of an exchange process, and therefore doesn't yet have to achieve perfection.

In every case, DSOs should initiate contact to downstream grid operators in a timely manner and clarify to what extent a GTP will be created, instead of waiting for them to initiate contact. Information exchange is necessary for both sides.

7.2.3 Dialogue with customers and municipalities



Initiate discussions with customers and municipalities	**These are the basis for more precise information in the 2023 GTP**

Figure 6: Dialogue with customers and municipalities

For 2022, discussions should be initiated promptly with the relevant network customers from internal customer analysis. In some cases, this will trigger the process of finding a decarbonization strategy for the customer. In 2023, a more reliable categorization of customers must be prepared in the GTP based on information from the customer. Direct discussions with manufacturers of customer facilities may also help here, if applicable.

Similarly, municipalities must also be involved in discussions early on, in order to properly position hydrogen and decarbonized gases in municipal heat planning and future climate-neutral energy supply. This will also feed into a more detailed analysis in 2023.

Initial findings from discussions, if available, should be considered under 7.1.

8 Technical analysis

8.1 Analysis of network components (objective: “full assessment”)

A large number of different network components are used in the gas distribution networks, e.g., pipeline materials, fittings, gas-technical equipment (e.g., gas pressure regulators and metering equipment) and in the connections to houses. In a first step, the pipeline materials will be recorded in the GTP in 2022 in accordance with G 410. Other components and systems will be recorded and tested in subsequent years. Details on the fundamental suitability of pipeline materials for H_2-readiness can be found in 12.3.2.

Note:

- The technical assessment of H_2-readiness is based on DVGW fact sheet G 221 and the technical regulation documents cited therein. A potential test procedure is provided here. This is not the subject of the GTP 2022, but it should be initiated in the company in order to be able to provide information on this in subsequent years.

- If you perform inspections of pipeline sections to determine the material, we recommend that you record all components directly. This will help you in subsequent years and avoid a potential duplication of work.

- Current construction sites should be used to close gaps in the documentation. See also G 402.

8.1.1 Sub-step 1: Analysis of the pipelines

Here the grid operator analyses its pipe network incl. grid connection lines with regard to:

- Material
- Diameter (DN)
- Pressure stages (MOP)
- Nominal pressure (DP)
- Year of construction
- Wall thickness (if known)
- Manufacturer (if known)

This data is usually reported by the network operators in the portal for statistics according to G 410. This data should be compared with the current status of the device information system for its accuracy and completeness (see 9.4).

Note:

- This is sufficient for the GTP 2022. Necessary individual assessments of H_2-readiness (see 12.3.2) are to be initiated.

- In particular, please check the reported amount of cast iron pipes for accuracy. Try to minimize the proportion of “unknown” materials and work actively to reduce any such position.

- The fundamental suitability of the pipeline materials for H_2-readiness must be taken into account when determining conversion zones. This can be particularly relevant for larger casting areas (retrofitting vs. methane supply).

8.1.2 Sub-step 2 (not 2022): Analysis of further pipeline components

Note: This section is not yet planned as a topic of investigation for the 2022 GTP. It is likely to be dealt with in 2023. We recommend that these components be addressed as soon as possible in order to be able to provide information in 2023.

8.1.3 Sub-step 3 (not 2022): Analysis of grid connection components (not TRGI)

Note: This section is not yet planned as a topic of investigation for the 2022 GTP. It is likely to be dealt with in 2023. We recommend that these components be addressed as soon as possible in order to be able to provide information in 2023.

8.1.4 Sub-step 4 (not 2022): Analysis of facilities

Note: This section is not yet planned as a topic of investigation for the 2022 GTP. It is likely to be dealt with in 2023. We recommend that these components be addressed as soon as possible in order to be able to provide information in 2023.

8.1.5 Outlook: DVGW database on H_2 suitability

First indications on the hydrogen compatibility of materials, components and products have been established through the DBI research project “H_2-Kompendium VNB” (these are presented in the compendia in a standardized form as profiles). Since not all components used in the German gas distribution network could be represented in the “H_2-Kompendium VNB”, the DVGW is working on the creation of a web-based database in which information on material compatibility and the evaluation of H_2 suitability will be made available in a binding manner for the entire industry. In addition to the evaluation for use with 100 volume percent hydrogen, methane-hydrogen mixtures with different hydrogen admixtures are to be taken into account.

The planned DVGW database is to be regarded as a “living system”, which is constantly being expanded and updated by the component manufacturers operating in the market and also by the DVGW institutes. The network operator has the role of reporting unknown components to the H_2 database via the interface. The missing values must then be supplemented with available data from both the manufacturer and the institute. The database is to be populated in two areas:

- Company information on deployed network components is made available to the DVGW. The DVGW defines a uniform data format (CSV) for this purpose. This data format is currently being prepared and will be published as soon as possible.

- The DVGW provides information on all available components regarding H_2 suitability. The findings from the DBI compendia (TSO, DSO, storage) will be used to initially populate the database.

The goal is to create a user-friendly database and link the two sources of information. Feedback from network operators will increase the level of detail of the database with regard to further components, parts and products during the period of use of the database application. In the long term (from 2023), the information is to be exportable from the database so that the network operators can integrate the results back into their respective systems (bidirectional exchange).

8.2 Examination of a sectioning of the conversion zones into subnetworks

Sectioning (network topological separation) of networks[4] into two or more separate conversion zones may be necessary depending on the:

a) Capacity analysis
b) Customer analysis
c) Target value analysis
d) Feed-in analysis
e) Network topology

With such sectioning, the following must be clarified:

- How long will the subnetworks remain separated? Separation, in some circumstances over a longer period of time, must be taken into account in the planning.
- Ensuring security of supply in the event of separation of network sections (if necessary, substitute supply/stabilization of liquid gas/air mixing plant)

For each subnetwork, the potential need for upgrading on the pipeline side is to be identified. According to these results:

- Clusters of pipelines that are not suitable for H_2 are to be checked for network hydraulic separability (climate-neutral methane supply if necessary).
- The necessary upgrades and their location in the investment plan can have a retroactive effect on the conversion sequence of the conversion zones (see 7.1.3).
- The construction of new, strategic feeder lines may need to be examined. In this context, major customers may also be given preference, if necessary.

Sectioning is helpful, for example, if the coupling points to upstream network operator(s) in a conversion zone are located on two or more different lines and the lines are converted in a staggered manner.

8.3 Network hydraulic analysis

General

The specific analysis depends on the planned mixing ratio for the feed-in, e.g., 20 volume percent, or 100 volume percent, and the conversion date (forecast target network capacity).

[4] Note: Sectioning in the sense of the market area conversion (streets, etc.) is not meant in this context.

Each (sub) network must be subjected to a network hydraulic analysis before conversion.

The initial focus should be on network sections that have been identified as particularly relevant in the capacity/customer analysis or that are particularly sensitive from a technical point of view (e.g., low-pressure networks).

Fundamentals

Due to the different physical properties and combustion characteristics of hydrogen compared to natural gas, such as calorific value, relative density, Wobbe index, etc., the hydraulic conditions change with increasing hydrogen content.

The calorific value of hydrogen is approx. 1/3 of that of natural gas (depending on the type of reference natural gas). Conversely, this means that if the chemically bound energy transport remains the same, the volume flow rate will increase in the same proportion for pure hydrogen.

If the pipeline diameter remains the same, the flow velocity will also increase in the same proportion, but there will be hardly any effect on the transport capability. The regulatory framework for H_2 flow velocities is currently being clarified by the DVGW.

Relevant for the gas supply is the operating pressure or the pressure drop that occurs in the case of a discharge. This initially increases proportionally with the hydrogen content, reaches a maximum at an admixture of approx. 80 volume percent H_2 and drops again somewhat up to 100 volume percent H_2, so that, depending on the reference natural gas, an approx. 20-30 percent higher pressure loss occurs in the case of pure hydrogen, which can lead to the specified minimum operating pressure not being reached.

A separate consideration must be made in the low-pressure networks. An admixture of hydrogen also leads to a change in density and a change in pressure gain behavior.

While the pressure gain for natural gas H is about 4.5 mbar/100 m height difference, the pressure gain for pure hydrogen increases to about 11 mbar/100m. This means that topographical differences can lead to pressure gains (buoyancy of the gas). Due to the particularly small pressure difference between feed-in pressure and maximum operating pressure in low-pressure networks, the maximum operating pressure (MOP) may be exceeded in the case of corresponding differences in altitude.

Procedure

A hydrogen-computable, hydraulic gas network model is to be created. Instructions for versions 10.1 and 10.2 of the STANET simulation tool can be found in the appendix.

Each network or subnetwork to be converted shall be calculated for the planned mixing ratio for the designated case and/or the target network capacities. The resulting operating pressures are to be compared with the specifications of the internal guidelines for permissible minimum operating pressures (for low-pressure networks also the maximum permissible operating pressure) in order to evaluate the network hydraulic suitability and to identify any weak points.

Table 1: Example analysis for 100 volume percent hydrogen

Network	DP (mbar)	**OP_{min} permissible** (internal specs) (mbar)	**OP_{min} calculated natural gas** (mbar)	**OP_{min} calculated 100% H_2** (mbar)	**MOP permissible** (mbar)	**OP_{min} calculated natural gas** (mbar)	**OP_{min} calculated 100% H_2** (mbar)	**Network hydraulic suitability**
High-pressure network 1	25,000	15,000	18,100	16,000	Relevant only for LP networks	Relevant only for LP networks	Relevant only for LP networks	Yes
High-pressure network 2	16,000	5,000	6,960	6,850	Relevant only for LP networks	Relevant only for LP networks	Relevant only for LP networks	Yes
High-pressure network 3	5,000	1,500	1,800	1,580	Relevant only for LP networks	Relevant only for LP networks	Relevant only for LP networks	Yes
Distribution network 1	5,000	150	220	210	Relevant only for LP networks	Relevant only for LP networks	Relevant only for LP networks	Yes
Distribution network 2	5,000	30	37	35	50	45	48	Yes
Distribution network 3	5,000	30	34	28	50	45	57	No

(Abbreviations: DP=design pressure; OP=operating pressure; MOP=maximum operating pressure; LP=low pressure)

As part of an analysis of measures, the restoration of the target state can be planned for Distribution Network 3. The measures are often associated with little technical effort, e.g., sectioning of networks, ring connections, increases in operating pressure or increasing the dimensions of pipelines.

9 Feedback for consolidation in overall GTP

Feedback deadline: 30.6.2022
Feedback template: GTP_2022_Netzbetreibernummer.xlsx
Send feedback to: GTP-H2vorOrt@dvgw.de

9.1 Conversion zones

Please document your conversion zones in your feedback. This is done on the basis of both the NIP and the municipalities being served via the Official Municipality Key.

✉ Feedback via the Excel template ([no.] = tab in the template):

[1] Company data (network operator name, network operator number, address, contact person).

[2] Assignment NIP - changeover zone: **EIC code**, NIP name, conversion zone number (network operator number + hyphen + incrementing number (starting with 01))

[3] Assignment of OMK to conversion zone: **official municipality key**, number of conversion zone.

Note:

- A conversion zone is assigned to one or more NIPs or municipality keys in each case.
- Please adapt the file name of the feedback template according to your network operator number (e.g., GTP_2022_9870105555555.xlsx).

9.2 Capacity and feed-in analysis

The methodology for querying H_2 demand is to follow the logic of the internal order, as is the case today for capacity reporting of natural gas. Here, upward consolidation is performed according to the reporting chain of the internal order. However, it is important here that both sides actively approach each other for reconciliation and that neither remains in a standby position.

The aim of the feedback to and subsequent consolidation by H2vorOrt in the entire GTP is to depict the hydrogen requirements or demands for climate-neutral gases in the respective conversion zones. The demands in the period from 2022 – 2032 per year as well as the years 2035, 2040 and 2045 are to be queried. The evaluation of the feedback serves to identify conversion zones that can be converted to 100 percent hydrogen as a matter of priority or at an early stage, or network areas in which (up to 20 volume percent) hydrogen is added to the methane supply.

✉ Based on the system used in the green gas query of the TSO gas, the following information is to be reported via the Excel file:

[1] Feed-in upstream: Recorded here is what volume of which gas is supplied at what time by the upstream network operator per conversion zone.

- Conversion zone
- Network operator number of upstream network operator
- Name of upstream network operator
- Output (2021, forecasts: 2022-2032, 2035, 2040, 2045)
  - CH_4 and
  - H^2

[2] Decentralized feed-in: This records the decentralized feed-in of methane or hydrogen.

- Conversion zone
- Market location
- Gas type [H2, CH_4, Bio-/EE-CH4]
- Output (2021, 2022-2032, 2035, 2040, 2045)

[3] Downstream network operator: In instances where there are downstream network operators, the extent to which GTP planning exists and fits together must be shown. This is to be recorded in the relevant tab of the Excel feedback template (conversion zone, network operator number down-stream network operator, name, consolidation status [GTP coherent / GTP not coherent / GTP not existing], output for methane and H2 over time (see above)).

[4]

- TSOs should also make compatible assumptions in their data for downstream network operators that do not create their own GTP. [5]
- Note: Companies that do not create a GTP are not explicitly named/highlighted in the overall GTP!

9.3 Customer analysis

In the overall GTP, so-called "heat maps" are created on the basis of NUTS-3 areas, among other things. These are not based on the conversion zones, but represent rather (independently of this) customer structures. One of the goals is to determine the distribution of customers with decarbonization needs ahead of time, the breakdown between RLM and SLP, as well as large customers (category 2, customer analysis). In the 2022 GTP, only work data will be collected. In the GTP 2023, this is to be extended to simultaneous peak load.

In order to be able to depict the whole of Germany more simply, we are using NUTS 3 areas and not the conversion zones[6]:

- NUTS (*French: Nomenclature des unités territoriales statistiques*)**:** indicates a hierarchical system for the clear identification and classification of spatial reference units of official statistics in the member states of the European Union.
- NUTS-3 refers to the 401 districts and independent cities, or in Baden-Württemberg, city districts.

Data collection assistance:

- Localization in NUTS-3:
    - The postal code is available for RLM and SLP customers in the market location
    - The assignment of postal code to NUTS-3 can be taken from this table[7]
- RLM customers: Output data is available
- SLP customers: Output based on last annual billing

✉ Feedback via the Excel template:

[7] Customer structure 1 – General
Basis for map representations (NUTS-3) for distribution of annual output/density of large customers per NUTS-3 area:

- NUTS-3
- Total output (=RLM (incl. Downstream grid operator (DGO) + SLP)
- RLM output (total, < 10 mil. kWh, ≥ 10 mil. kWh, ≥ 50 mil. kWh, ≥ 100 mil. kWh)
- Downstream grid operator (DGO) output (total downstream NIPs in NUTS-3 area)
- SLP output

[5] The gas quantities currently purchased from the downstream network operators are known from the internal order. If no GTP is available, a transformation matching the own network section is to be assumed with a similar volume development.

[6] Source: https://de.wikipedia.org/wiki/NUTS

[7] https://ec.europa.eu/eurostat/de/web/nuts/correspondence-tables/postcodes-and-nuts

[8] **Customer structure 1 – Acute Decarbonization needs**
RLM customers per NUTS-3 area subject to early decarbonization requirements due to taxonomy, EU-ETS, market or other reasons.

- NUTS-3,
- Output, number (total; broken down by requirement source: taxonomy, EU-ETS, market-based, other)

9.4 Technical analysis

Feedback is only to be provided for 8.1: Please update your reporting to the DVGW gas-water statistics according to G 410 as accurately as possible. Based on this data, DVGW will generate statements that are not attributable to individual companies for the overall GTP.

10 Project checklist GTP creation

Feedback deadline: 30.6.2022
Feedback template: GTP_2022_Netzbetreibernummer.xlsx
Send feedback to: GTP-H2vorOrt@dvgw.de

1. Create an initial breakdown into conversion zones based on the capacity analysis (7.1.1) and feed-in analysis (6.1).

2. Conduct an initial discussion with your upstream grid operator / TSO and downstream grid operators and adjust the conversion zones if necessary. Maintain a regular exchange of information on changes (see 7.2).

3. Perform the customer analysis and analyze the impact on the conversion zones (7.1.2).

4. Document at which network points sectioning may be necessary in order to map the conversion zones in this manner (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

5. Conduct the H_2-readiness analysis of your pipeline materials according to **Fehler! Verweisquelle konnte nicht gefunden werden.** and update the gas-water statistics pursuant to G 410 according to 9.4. If required, conduct a network hydraulic analysis at relevant points according to **Fehler! Verweisquelle konnte nicht gefunden werden.**.

6. Document your conversion zones in the feedback template (fill in tabs 1-3) according to **Fehler! Verweisquelle konnte nicht gefunden werden.**.

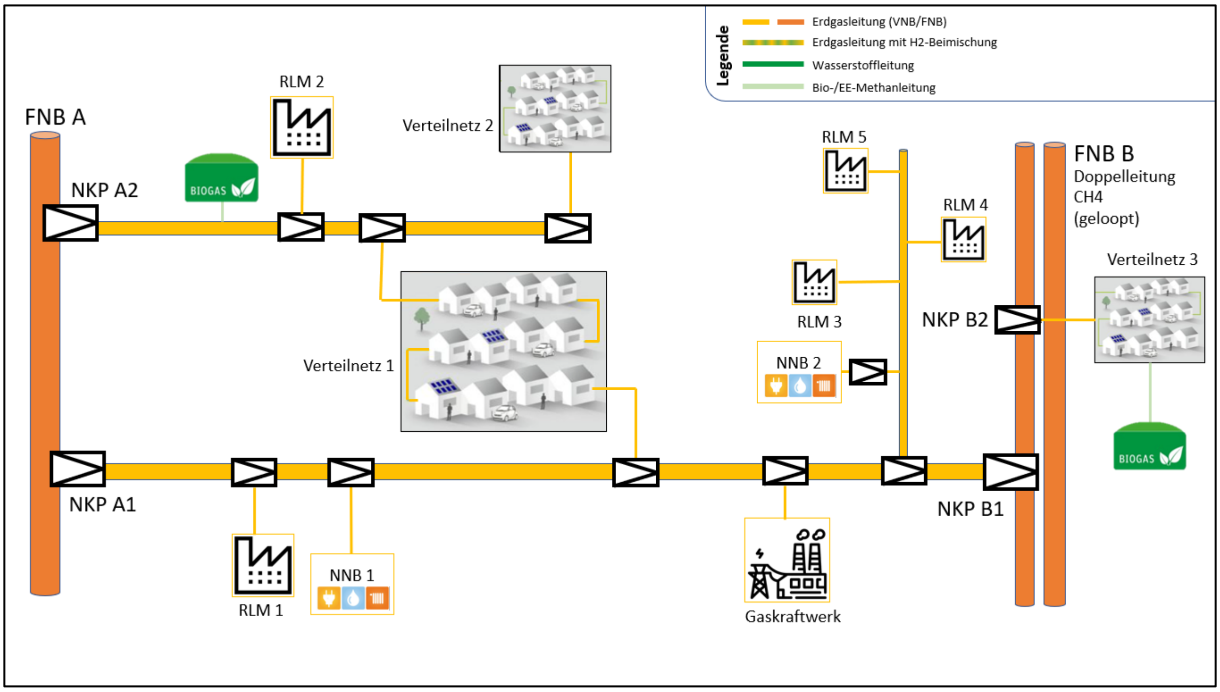
7. Carry out the internal target value analysis according to 7.1.3, include the analysis of your upstream grid operator and document the results in the feedback template (tabs 4-6) according to **Fehler! Verweisquelle konnte nicht gefunden werden.**. Discuss this with your upstream grid operator.

8. Fill in the customer structure feedback template (tabs 7-8) as per 9.3. Please ensure to use the latest version of the feedback template from the website.

9. Be sure to name the feedback form correctly with your network operator number (e.g., GTP_2022_98701055555.xlsx) and send the feedback form to:GTP-H2vorOrt@dvgw.de

11 Example analyses

Sample data can be found in the file “(Beispiel)_GTP_2022_98701055555.xlsx”.



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'UGO' statt ‚NBB‘
'Conversion zone' statt 'Umstellzone'
'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

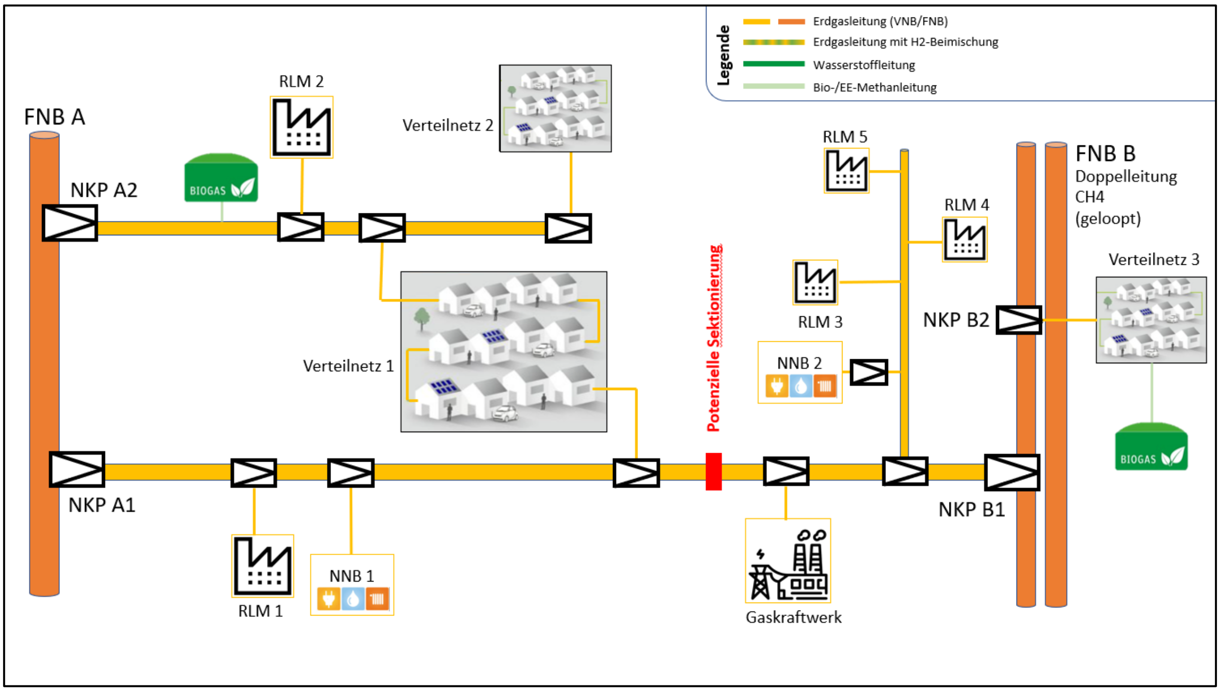
The example distribution system operator under consideration procures natural gas via the two upstream TSOs A and B. Three high-pressure networks supply five RLM customers, two downstream network operators, a gas power plant, and two distribution networks. Distribution network 3 is fed directly via TSO B as well as via a biogas plant.

<u>**Capacity analysis**</u>

With respect to the network coupling points, the following is the result of the internal ordering (see 7.1.1):

NIP	A1	A2	B1	B2
Output	565 GWh	600 GWh	595 GWh	248 GWh
Capacity	185 MW	200 MW	200 MW	90 MW

The first candidates for conversion zones result from both long-distance pipelines. Here, the intermeshing of line B with line A via NIP B1 is an issue to be resolved. Testing (see under "Sectioning") reveals that sectioning is technically and supply-wise possible here:



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline

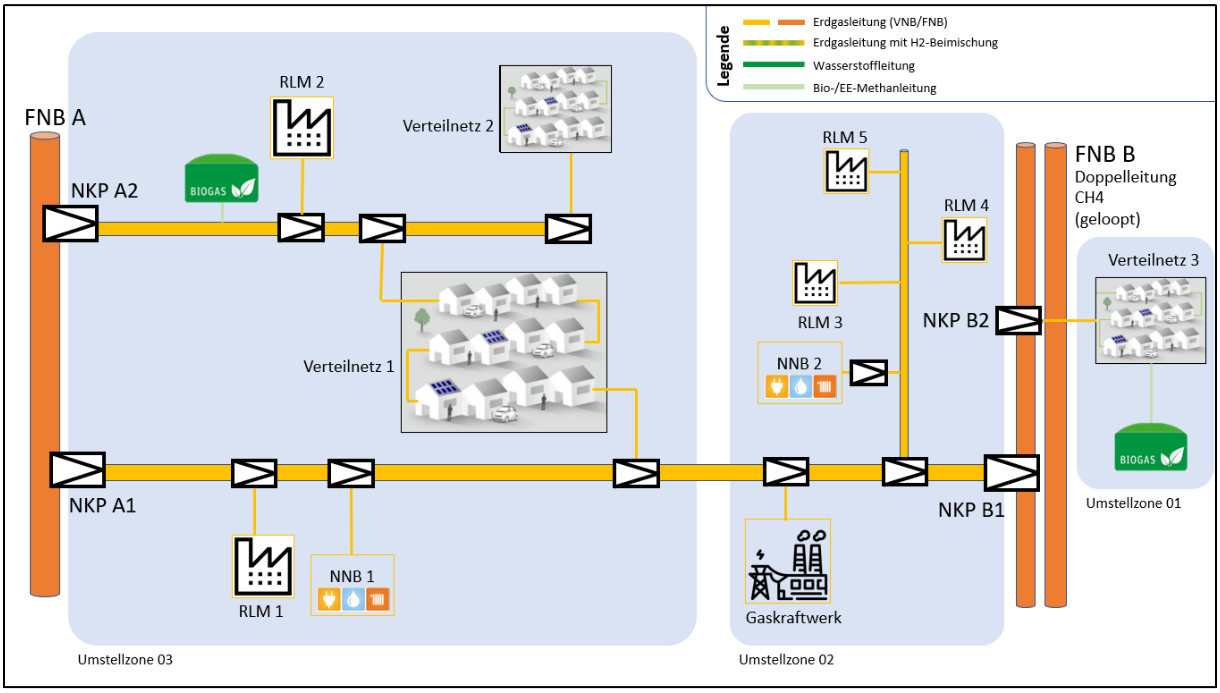
Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'
'Potential sectioning' statt 'Potenzielle Sektionierung'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Note: Line TSO B is looped, i.e., there are two parallel lines here, both of which transport natural gas in its initial state. This enables a gradual conversion, since one of the two lines is first converted to H_2 and the other continues to be supplied with natural gas. Accordingly, this is not possible with the line from TSO A.

In an initial discussion with the supplying TSOs (see 7.2.1), it emerged that a supply with H_2 via pipeline B will presumably start first. TSO B will transport hydrogen in one of the dual pipelines starting in 2029, whereas TSO A foresees hydrogen transport in 2035, according to its plans.

Based on this information, an initial picture emerges for the conversion zones:



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

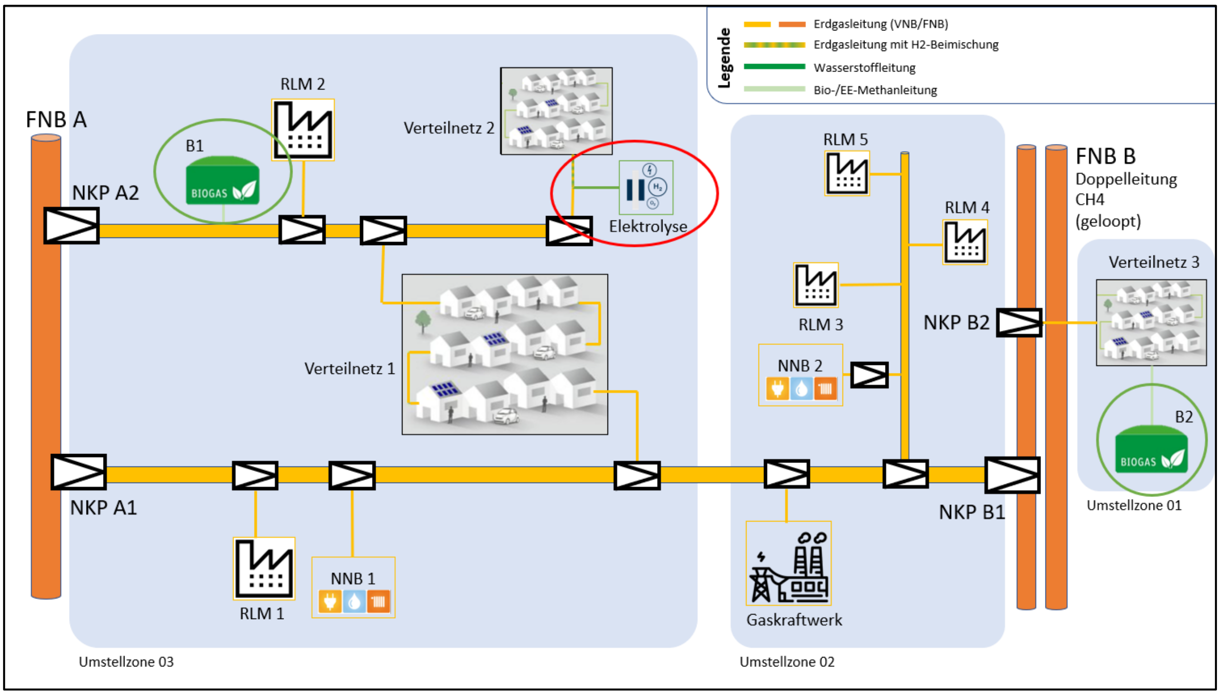
'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Feed-in analysis

There are 2 biomethane plants in the grid area:

- 24 GWh p.a. near NIP A1
- 20 GWh p.a. in distribution grid 3

Planned electrolysis from 2031: 40 GWh p.a. in distribution grid 2, resulting in an admixture in distribution grid 2.



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Electrolysis' statt 'Elektrolyse'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Customer analysis

There are 6 RLM customers, including one gas-fired power plant, and two downstream network operators in the regional network. In distribution network 1 there are 12 additional RLM customers and 13,000 SLP customers. Distribution grid 2 has 16 RLM customers and 20,000 SLP customers. In distribution network 3 there are 9 RLM customers and 8,000 SLP customers.

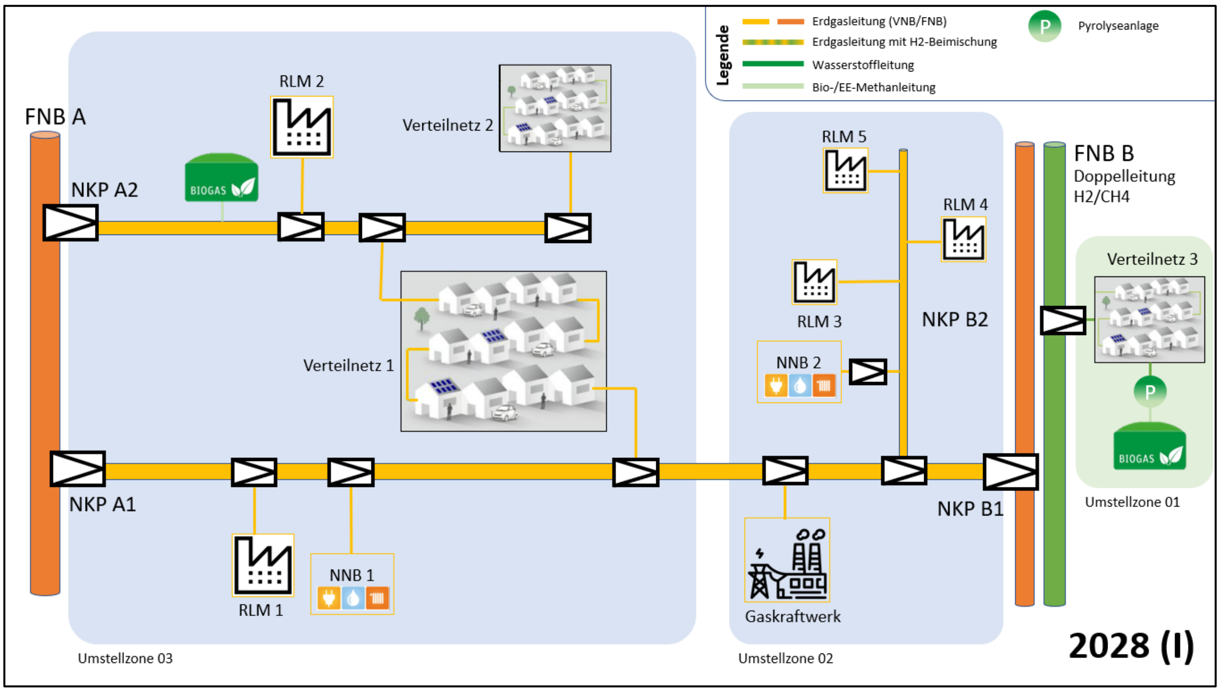
Feedback according to 9.3 can be found in the sample feedback "(Beispiel)_GTP_2022_98701055555.xlsx" [currently still in progress].

Target value assessment

Delivery situation and customer requirements result in the following conversion sequence:

- Changeover conversion zone 01: 2028
- Changeover conversion zone 02: 2029
- Conversion zone 03:
    - Admixture of distribution network 2: 2031
    - Changeover: 2035

2028



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline
Pyrolysis plant

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Electrolysis' statt 'Elektrolyse'
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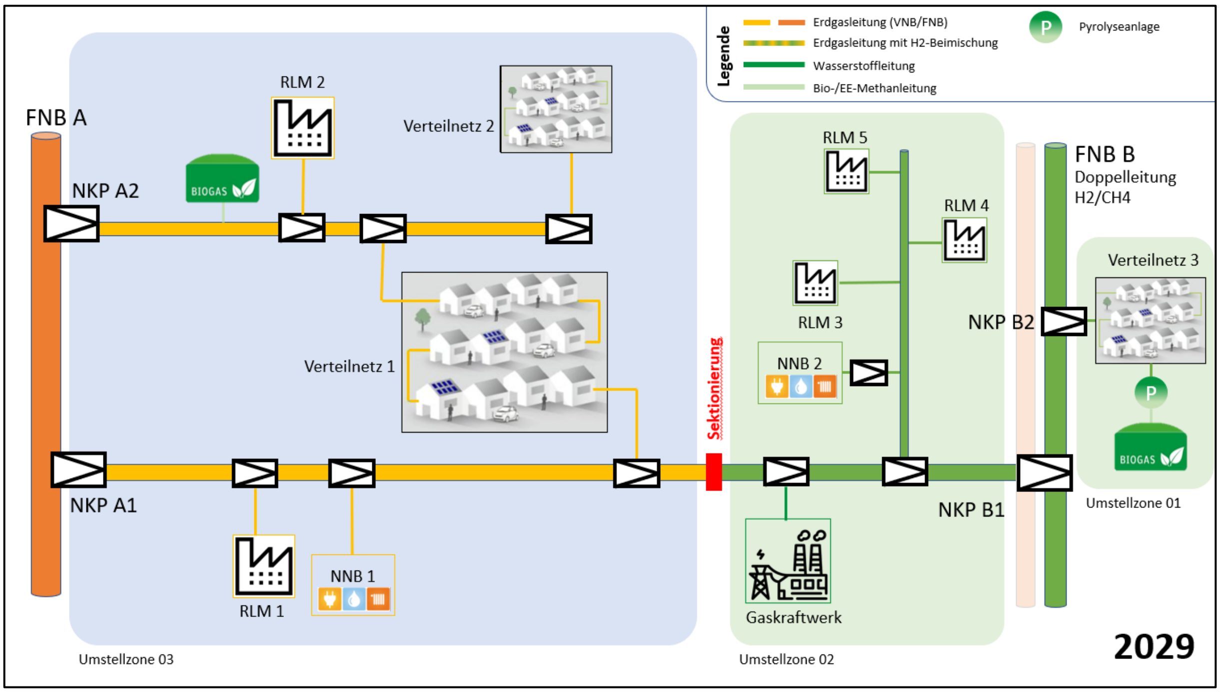
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

With the changeover of conversion zone 2 to hydrogen, a solution must be found for the biogas feed-in. Distribution network 3 is to be supplied with 100 percent hydrogen, so it is advisable to produce hydrogen from biomethane. This can be achieved, for example, by steam reformation (carbon neutral) or pyrolysis (carbon negative emissions). In this case, the opportunity is seized to generate negative emissions by means of pyrolysis, which are additionally marketable.

2029



Legende:

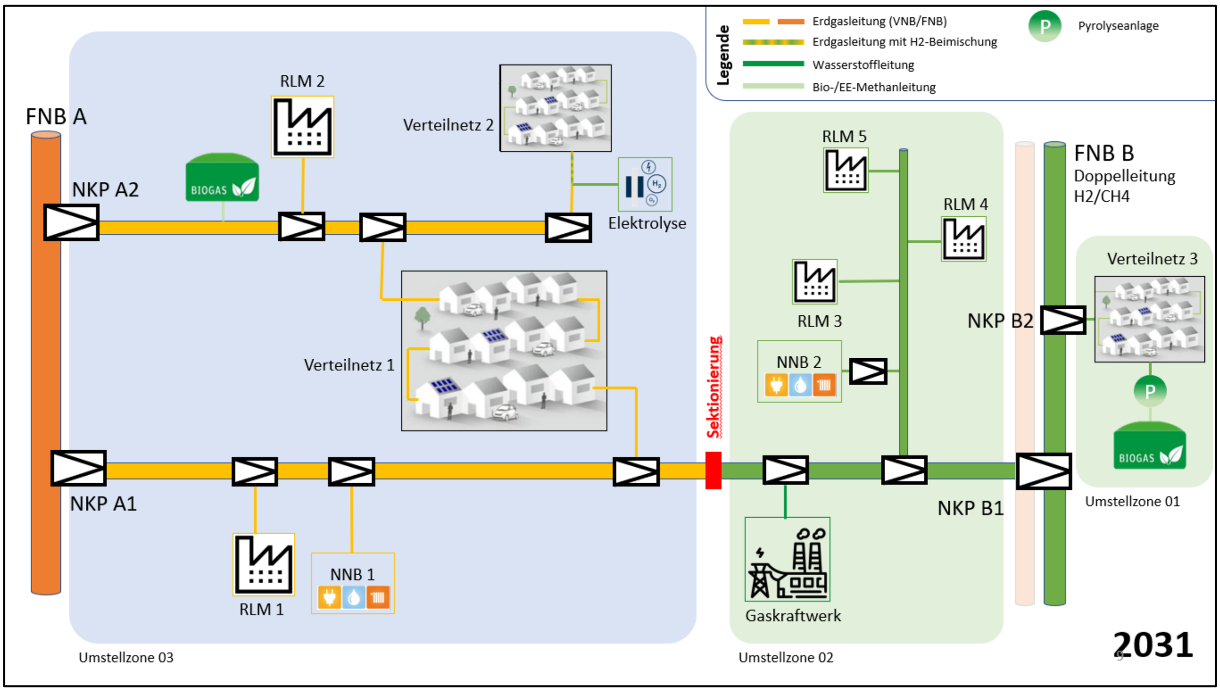
Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline
Pyrolysis plant

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Sectioning' statt 'Sektionierung'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Thanks to the sectioning carried out in 2028, conversion zone 02 can be converted to 100 percent hydrogen in 2029.

2031



Legende:

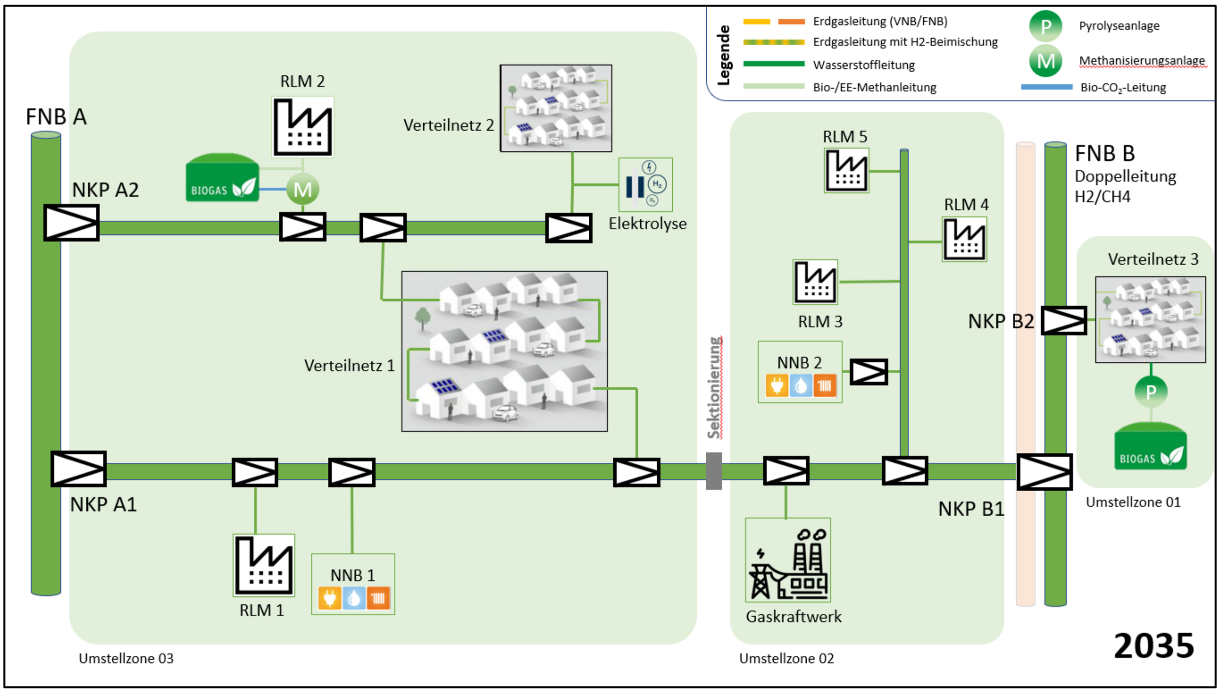
Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline
Pyrolysis plant

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Electrolysis' statt 'Elektrolyse'
'Sectioning' statt 'Sektionierung'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Distribution network 2 is now supplied with a hydrogen admixture of 20 volume percent via electrolysis. Refeeding into the high-pressure line does not take place.

2035



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline
Pyrolysis plant
Methanation plant
Bio-CO_2 pipeline

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Electrolysis' statt 'Elektrolyse'
'Sectioning' statt 'Sektionierung'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

TSO A now also supplies 100 percent hydrogen, which means that conversion zone 03 can be changed over. Customer RLM 2, which uses methane materially, continues to be supplied with methane: the biomethane plant now feeds directly into its supply pipeline. In addition, the climate-neutral CO_2 produced in the biomethane processing plant is used for the methanation of hydrogen from the main line, increasing the available power. Distribution network 2 is now also supplied with 100 percent H_2. With the completion of the conversion, the sectioning between conversion zones 02 and 03 can be removed again.

You will find the corresponding working values in the example feedback "(Beispiel)_GTP_2022_98701055555.xlsx".

Technical analysis

The technical analysis accompanies the steps described above.

Sectioning

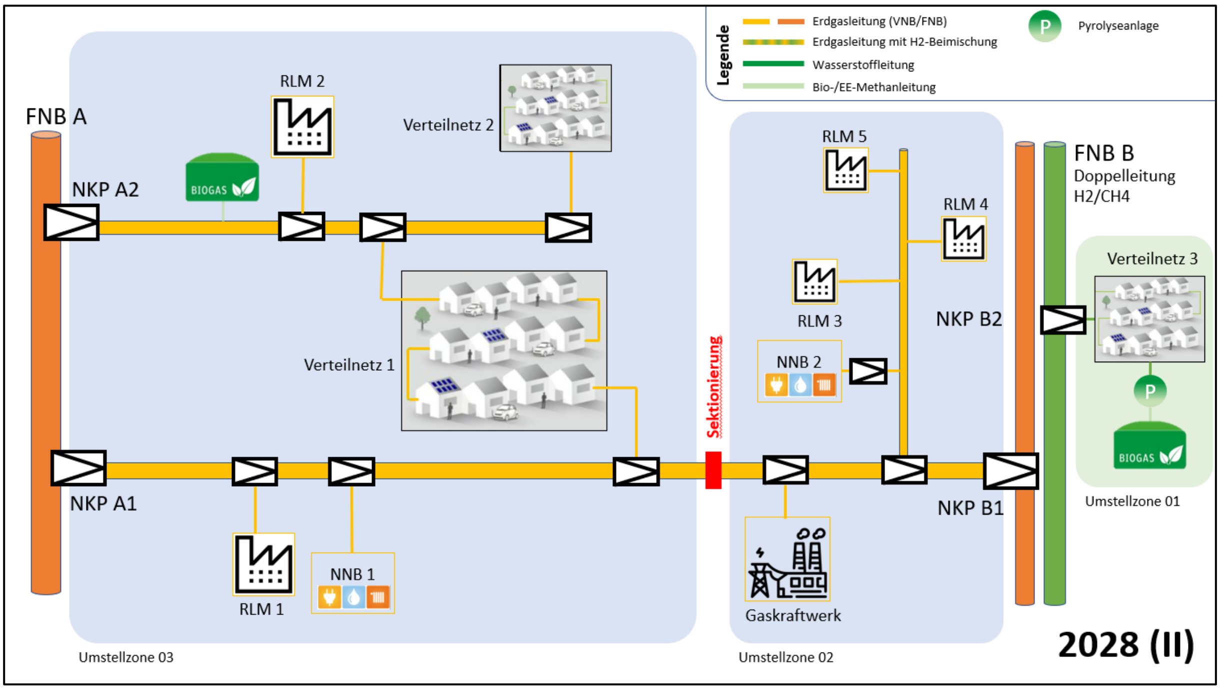
TSO B will transport hydrogen in one of the dual lines from 2029, whereas TSO A foresees hydrogen transport in its plans in 2035.

It is the DSO's goal, in terms of decarbonization, to supply as high a proportion as possible in the high-pressure network between NIP A1 and NIP B1 with NIP B1 and hydrogen.

The customer analysis has shown that these are RLM customers with no technical criticality (except RLM 2 with material use). The gas plant requires conversion from natural gas to hydrogen as soon as possible due to decarbonization commitments. Downstream grid operators will be involved early in the transformation planning process.

The grid hydraulic and capacity analysis has shown that a separation between the gas-fired power plant and the feed-in to distribution grid 1 has to take place or a sectioning into conversion zones 02 (hydrogen) and 03 (natural gas). This must be completed at the latest before the changeover of conversion zone 02.

However, in this operating state, two separate high-pressure stub networks are created from an interconnected high-pressure network.



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline
Pyrolysis plant

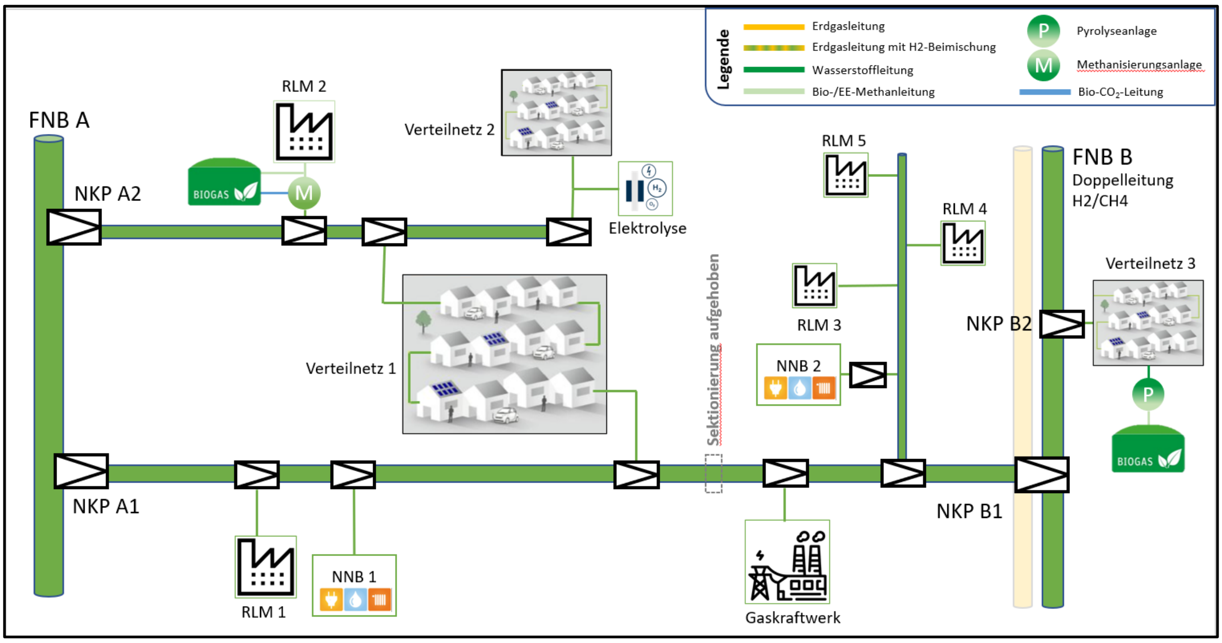
Zu ersetzen:
'TSO' statt 'FNB

'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Sectioning' statt 'Sektionierung'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

From 2035, TSO A can also switch to hydrogen, so that a new operating state is established (analogous to the current supply situation) and sectioning is consequently discontinued.

Due to the dual feed-in of the high-pressure network with NIP B1 and A1, the DSO creates operational flexibilities from the dispatching point of view as well as in the event of decommissioning, disruptions, and construction sites.



Legende:

Legend
Natural gas pipeline (DSO/TSO)
Natural gas pipeline with H_2 admixture
Hydrogen pipeline
Bio-/RE methane pipeline
Pyrolysis plant
Methanation plant
Bio-CO_2 pipeline

Zu ersetzen:
'TSO' statt 'FNB
'NIP' statt 'NKP'
'Distribution network' statt 'Verteilnetz'
'Electrolysis' statt 'Elektrolyse'
'Sectioning discontinued statt 'Sektionierung aufgehoben'
'UGO' statt ‚NBB'
'Conversion zone' statt 'Umstellzone'

'Gas power plant' statt 'Gaskraftwerk'
'Double pipeline CH4 (looped)' statt 'Doppelleitung CH4 (geloopt)

Pipeline network materials

The following aggregated picture emerges from the analysis of the pipeline network and the network connection lines with regard to materials, diameters, pressure ratings, years of construction as well as wall thicknesses and the reconciliation in the portal for the statistics, in accordance with G410:

Inventory data for network connections (≤5 bar)

MOP			**Diameter**			**Material**[a]		**Construction year**	
	Quantity	Length [km]	DN	Outer diameter dn (synthetics)	Length [km]		Length [km]		Length [km]
≤0.1 bar	7,950	109	≤DN 25	≤DN 32	109	PVC		Vor 1920	
>0.1 bar -1 bar	12,824	176	>DN25 -DN50	>DN32 -DN63	114	PE other (e.g., PE50, PE63)		1920-1929	
>1 bar -5 bar	4	1	>DN50	>DN63	63	PE80		1930-1939	
			Unknown	Unknown		PE100 (also PE RC)	95	1940-1949	
						PE-X	156	1950-1959	
						Other synthetics		1960-1969	14
						Steel	35	1970-1979	16
						Ductile iron (GGG)		1980-1989	78
						Unknown		1990-1999	63
								2000-2009	65
								2010-2019	48
								2020-2029	2
								Unknown	
Total		**286**			**286**		**286**		**286**

[a] Other materials are to be assigned accordingly

Inventory data for gas pipelines <16 bar without network connections of distribution network operators

MOP		Diameter			Material[a]		Construction year	
Quantity	Length [km]	DN	Outer diameter dn (synthetics)	Length [km]		Length [km]		Length [km]
≤0.1 bar	342	≤100	≤110	329	PVC		Vor 1920	
>0.1 - 1 bar	985	>100-200	>110-225	614	PE other (e.g., PE50, PE63)		1920-1929	
>1 - 5 bar	63	>200-350	>225-355	521	PE80		1930-1939	
>5 - 16 bar	134	>350-500	>355-500	44	PE100 (also PE RC)	1245	1940-1949	
		>500-700		16	PE-X		1950-1959	78
					Other synthetics		1960-1969	144
					St (PE with KKS)	60	1970-1979	87
		>700-1000			St (PE without KKS)	195	1980-1989	407
					St (bituminized with KKS)		1990-1999	265
					St (bituminized with-out KKS)		2000-2009	283
					Ductile iron (GGG)		2010-2019	238
					Gray cast iron (GG) treated/refurbished	23	2020-2029	21
					Gray cast iron (GG) untreated		Unknown	1
					Unknown	1		
Total	**1,524**			**1,524**		**1,524**		**1,524**

[a] Other materials are to be assigned accordingly

MOP		Diameter			Material[a]		Construction year	
	Length [km]	DN	Outer diameter dn (synthetics)	Length [km]		Length [km]		Length [km]
>16-25 bar	72	Unknown			Andere Kunststoffe (e.g., Aramide)		Before 1920	
>25-35 bar		≤100			St (PE with KKS)	72	1920-1929	
>35-45 bar		>100-200			St (PE without KKS)		1930-1939	
>45-55 bar		>200-350			St (bituminized with KKS)		1940-1949	
>55-65 bar		>350-500		72	St (bituminized with-out KKS)		1950-1959	
>65-75 bar		>500-700			Unknown		1960-1969	
>75-85 bar		>700-1000					1970-1979	72
>85-95 bar		>1000					1980-1989	
>95-100 bar							1990-1999	
							2000-2009	
>100 bar							2010-2019	
							2020-2029	
							Unknown	
Total	**72**			**72**		**72**		**72**

[a] Other materials are to be assigned accordingly

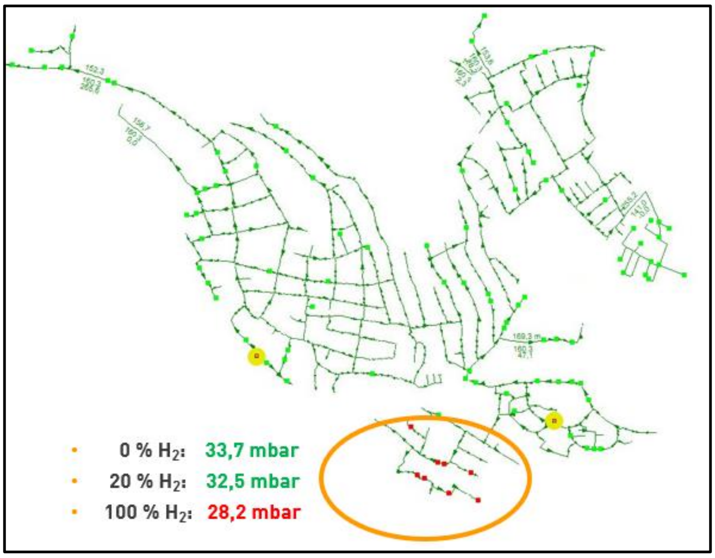
Inventory data for gas pipelines >16 bar without network connections of distribution network operators

Network hydraulic analysis

A network hydraulic analysis of the high-pressure networks and of distribution networks 1 and 2 has shown compliance with the minimum pressure required in accordance with the company's internal guidelines/planning assumptions at 100 percent hydrogen.

Consequently, a hydrogen admixture by electrolysis can also be realized in distribution grid 2 in 2031 from a grid hydraulic point of view.

Distribution grid 3 is an exception, since the permissible minimum pressure of 30 mbar was not reached:



33.7 mbar
32.5 mbar
28.2 mbar

A subsequent analysis of measures has shown that a sectioning of the network can restore the target state at 100 percent hydrogen with little technical effort.

Likewise, a network hydraulic review of the sectioning of the high-pressure network between NIP B1 and A1 for the years 2028 onwards has shown that the separation between the gas power plant and the feed-in into distribution network 1 must be carried out, otherwise the permissible minimum pressure in the high-pressure network would no longer be maintained in the calculated peak load case and the maximum plant capacity at NIP B1 would be mathematically exceeded.

12 Appendices

12.1 Additional remarks on the feed-in analysis: Feeding hydrogen into natural gas grids

By expanding the definition of the term in EnWG § 3 No. 10c, hydrogen is treated the same as biogas, provided that the electricity used for electrolysis is verifiably derived predominantly from renewable energy sources. As a result of this equivalence, Part 6 ("Biogas") of the Gas Network Access Ordinance (GasNZV – Gasnetzzugangsverordnung) also applies to hydrogen, so that the same privileges that apply to biogas are now also applicable to hydrogen:

- Grid connection obligation
- Cost sharing for grid connection: 75 percent grid operator / 25 percent connection user
- Grid operator must ensure availability of grid connection (96 percent)
- Standardized procedure for checking connections
- Priority grid access
- Extended balancing period

Furthermore, the requirements of DVGW work sheet G 260 must be met with regard to gas quality, which hydrogen does not fulfil due to its differing physical and combustion properties compared to biogas. Hydrogen fed into a natural gas network is therefore considered an additive gas as opposed to biogas, which is considered an exchange gas. According to DVGW work sheet G 260, additive gases can be added to the base gas in limited quantities, whereby the requirement for similar combustion behavior of the gas mixture determines the amount of admixture.

Provided that the combustion characteristics are observed in accordance with the regulations, the admixture of hydrogen in the single-digit percentage range into the natural gas network is not critical. The limiting factors here are applications such as CHP units or CNG filling stations, which due to fuel standards, for example, limit the hydrogen content to 2 volume percent. A determination of the H_2-sensitive customers in the region of the feed-in is therefore essential when examining the grid connection proposal. It should additionally be taken into account that the hydrogen must be fed in almost all year round, i.e., also in the warmer months of the year when the natural gas flow rates are reduced. The amount of hydrogen that can be fed into the grid is therefore determined by the annual natural gas flow rate at the feed-in point, taking into account the hydrogen compatibility of the customers connected to the grid and the hydrogen content already present in the natural gas.

The feed-in of (green) hydrogen will mainly take place when sufficient renewable energy from wind and PV is available. In contrast, there are times when hardly any renewable electricity is available and no hydrogen can be fed into the natural gas grid. This intermittent H_2 feed-in leads to fluctuating gas qualities, which can lead to major problems, especially for some industrial customers. Acceptance by customers can be increased by developing concepts that guarantee an almost constant H_2 concentration in the natural gas grid.

The position paper prepared by the BNetzA in 2014 on applying the regulations on the feed-in of biogas to the feed-in of hydrogen and synthetic methane into gas grids provides highly valuable information, particularly on the topics of connection availability and minimum feed-in capacity. In addition, a detailed test procedure for the uniform processing of grid connection requests is currently being developed in the "Hydrogen feed-in requests" project group, initiated by the DVGW.

12.2 Additional remarks on the customer analysis

12.2.1 The overarching European legal framework

The decarbonization of CHP is affected like all other sectors by the European climate targets 2030 and 2050. Consequently, a pathway to reduce the carbon emissions needs to be prepared for all such plants. Depending on their size, they either fall under the ETS emissions trading or the non-ETS sector. Now that the 2030 targets have been adjusted from -40 percent to at least -55 percent, the reduction pathways for ETS and non-ETS are also intensified.

The Renewable Directive stipulates that by 2030, buildings must be supplied with 49 percent renewable energy. This means that the heat supply from district and local heating networks must also comply with this target.

This is further reinforced by the Energy Efficiency Directive, which sets specific targets on how district heating must be decarbonized (Art. 24), requiring at least 50 percent renewable primary energy or waste heat in 2035, but with a minimum of 20 percent renewables.

Since December 2021, there has been a draft for the Buildings Directive, which from 2030 onwards will only permit the construction of zero-energy buildings, which may only obtain their energy independently or from a nearby energy community. A district heating supply is only permitted if it is fed entirely from renewable energy sources.

In addition, the rules of the laws on sustainable reporting and subsidies must be observed. In the future, a growing number of companies will be required to expand their reporting to include CAPEX and OPEX in sustainable products and activities as defined in the taxonomy.

The proposal for the classification system was developed by an expert panel commissioned by the EU-COM. 70 processes were selected as relevant.

Forestry: Afforestation, forest management	**Water: Collection/treatment**
Agriculture: Livestock, manure management	**Waste water: Purification, sewage sludge, sewage gas**
Industrial production: Steel, cement, H2, plastics	**Waste: Landfill gas, CCS/CCU, carbon networks**
Electricity: Production, grids, heat pumps	**Transport: Trains, public transport, petrol stations, cars**
Heat/steam/cooling: Production, grids	**Information/communication: Server farms**
Gas: Grids, biogas, H2 storage	**Construction/housing industry: Renovations, new construction**

Figure 7: **Status February 2022, Source: Taxonomy Report: Technical Annex**

In order to make taxonomy-compliant investments in the future or to declare products as taxonomy-compliant, the companies or CHP plants concerned must comply with defined carbon emission limits. As things stand, new CHP plants that run on natural gas, for example, are only considered taxonomy-compliant if they abide by various ambitious rules.

In the future, subsidies from KfW or Bafa may also only be awarded to gas CHP due to the new subsidy rules – valid from 1.1.2023 – if a clear path to decarbonization of the individual plant is provided. Based on the taxonomy, this would be given by the use of 100 percent renewable and climate-neutral gases as early as 2035. The fulfilment of this requirement in the balance sheet should be taken into account in the national design of the downstream rules. Regardless of this, every new plant, but also every conversion, must be designed for operation with hydrogen.

In the future, certain industries will pay more attention to ensuring that all products and processes in the supply chain are taxonomy-compliant, as the market, banks and owners will demand this.

A hydrogen transformation of the existing gas infrastructure is indispensable to achieve the European policy goals in a timely manner.

12.2.2 Classification of industrial and commercial combustion processes

12.2.2.1 Relevant European regulations

All relevant European laws are currently being revised by the so-called “Fit for 55” package. Many of them affect industrial customers and gas-fired power plants/gas CHPs. Of particular importance are the rules for emissions trading (ETS), the Renewable Energy Directive, the Energy Efficiency Directive, the Buildings Directive, and the sustainable financing (taxonomy) and the rules concerning public funding support.

For industrial customers, the reduction of the CO_2 path is particularly crucial, as on the one hand more allowances are being withdrawn from the market and CO_2 prices are expected to rise further (currently at €90/t). In Germany, there are about 1900 installations in emissions trading. The list includes power plants and CHP plants both in industrial companies and from the energy sector, as well as other customer plants, e.g., for the production of cement and cement bricks, steel, aluminum, tiles, ferrous metals, chemicals, paper, glass, plaster, lime, pulp.

It follows from these considerations that the following industrial sectors/electricity generation in particular should be considered for a rapid conversion to climate-neutral gases and provide indications as to which network sections would need to be converted at an early stage:

- Steel production, Rolling mills etc.
- Building materials industry: Cement, cement bricks, bitumen mixing plants ...
- Chemical industry
- Refineries
- Glass, ceramics
- Plastics production
- Automobile manufacturers and suppliers
- Paper
- Bricks and tiles
- Food industry/agriculture: Dairies, breweries, grain dryers, grass dryers, etc.
- CHP, industrial CHP, power generation in general

12.2.2.2 Sensitive combustion processes

In industry and commerce, gas is used both as an energy source and as a raw material. The following considerations serve exclusively to identify processes/consumers that may have an influence on the conversion sequence as well as the selected conversion path (direct to 100 percent or use of the intermediate stage 20 volume percent).

The sensitivity of the processes with regard to hydrogen has several dimensions: Safety, efficiency, environmental impact, impact on product quality (

Sector		**Process**	**Efficiency**				**Safety (emissions + thermal overload)**				**Product quality**			
			Variation range Wobbe index / heating or calorific value to the set value											
			±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %
Heat-ing	Process	Light radiator*												
		Dark radiator*												
		Hot air generator*												
	Room	Heat and steam boilers												
		Direct and indirect drying												
Energy supply		Gas turbines Diffusion mode DLE Mode												
		Gas motors												
Metallurgy		Preheating (metals)												
		Thermochemical heat treatment												
		Endogenous gas production												
		Galvanising processes												
		Melting processes (non-ferrous metals)												
Ceramics		Lime kilns, calcination of clays												
		Brick production												
		Porcelain firing												
Glass		Glass melts (container glass)												
		Glass melts (pane glass)												
		Glass melts (special glass)												
		Feeder and cooling (tempering)												
Chemical		Chemical and plastics industry												

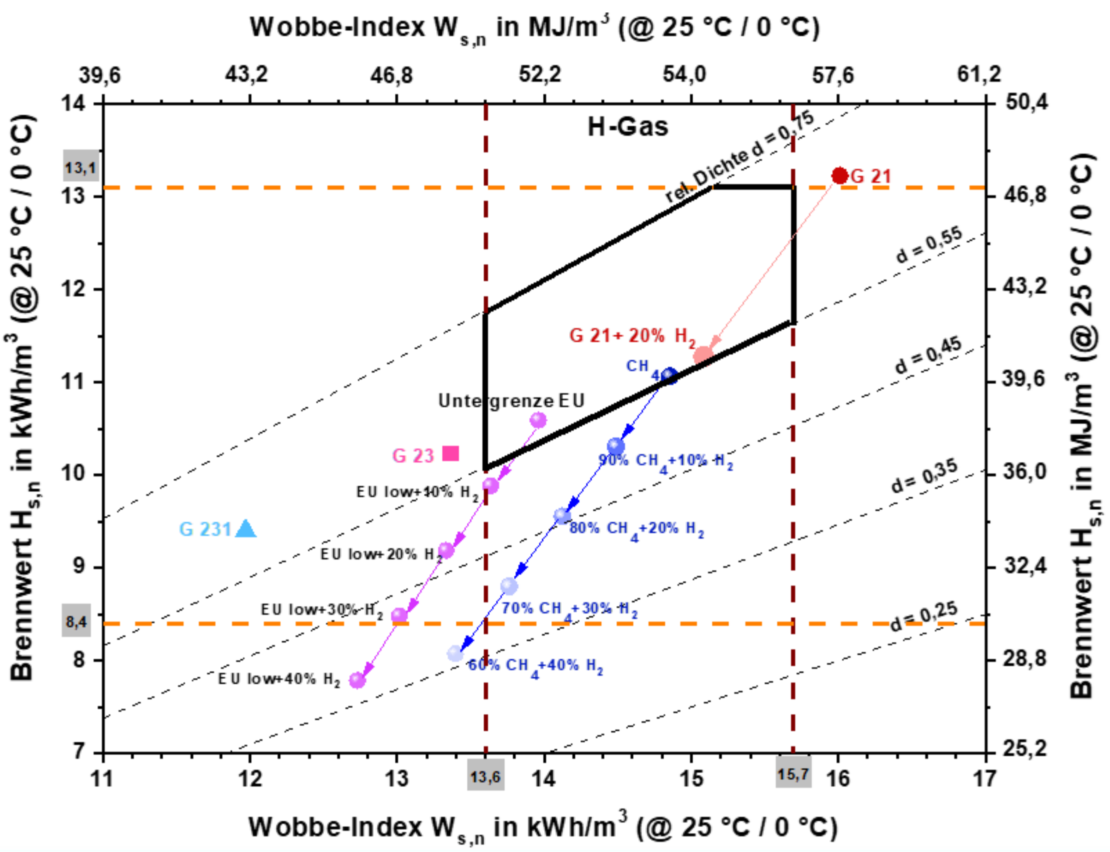
Basis: No compensatory measures

Light radiator*, dark radiator*, warm air heater*: Here, "product quality" refers to space heating quality

No need for action
Partly some need for action
Need for action

).

Specific hydrogen compatibility studies are currently underway. Previous findings from investigations regarding fluctuations in the quality of natural gas constitute an initial basis for assessing the sensitivity of the processes to hydrogen. With an admixture of 20 volume percent hydrogen, gas quality characteristics change. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows an example of the influence of hydrogen admixtures on the gas characteristics.



Brennwert = calorific value
rel. Dichte = rel. density
Untergrenze = lower boundary
→ Komma zu Punkte Ändern (z.B. 39,6 → 39.6)

Figure 8: Influence of hydrogen admixtures (0-40 percent) on the gas parameters (Source: DVGW Roadmap Gas 2050 based on DVGW G 260)

Investigations of industrial combustion processes with regard to changes in the Wobbe index show a clear sensitivity of the processes (

Sector		Process	Efficiency				Safety (emissions + thermal overload)				Product quality			
			Variation range Wobbe index / heating or calorific value to the set value											
			±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %
Heat-ing	Process	Light radiator*												
		Dark radiator*												
		Hot air generator*												
	Room	Heat and steam boilers												
		Direct and indirect drying												
Energy supply		Gas turbines Diffusion mode DLE Mode												
		Gas motors												
Metallurgy		Preheating (metals)												
		Thermochemical heat treatment												
		Endogenous gas production												
		Galvanising processes												
		Melting processes (non-ferrous metals)												
Ceramics		Lime kilns, calcination of clays												
		Brick production												
		Porcelain firing												
Glass		Glass melts (container glass)												
		Glass melts (pane glass)												
		Glass melts (special glass)												
		Feeder and cooling (tempering)												
Chemical		Chemical and plastics industry												

Basis: No compensatory measures

Light radiator*, dark radiator*, warm air heater*: Here, "product quality" refers to space heating quality

No need for action
Partly some need for action
Need for action

). The changes in the Wobbe index determined from **Fehler! Verweisquelle konnte nicht gefunden werden.** through hydrogen admixtures can, in combination with

Sector	Process	Efficiency	Safety (emissions + thermal overload)	Product quality
		Variation range Wobbe index / heating or calorific value to the set value		

			±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %
Heat-ing	Process	Light radiator*												
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		Hot air generator*												
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		Direct and indirect drying												
Energy supply		Gas turbines Diffusion mode DLE Mode												
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Metallurgy		Preheating (metals)												
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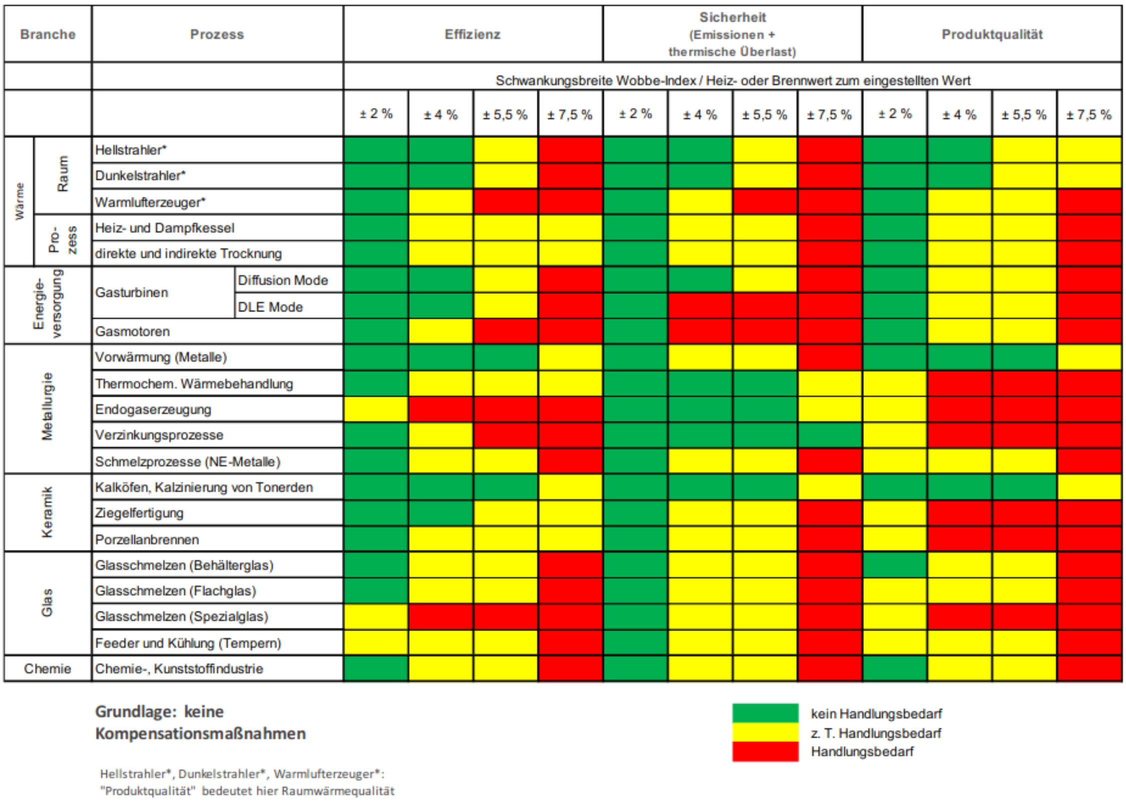
		Endogenous gas production												
		Galvanising processes												
		Melting processes (non-ferrous metals)												
Ceramics		Lime kilns, calcination of clays												
		Brick production												
		Porcelain firing												
Glass		Glass melts (container glass)												
		Glass melts (pane glass)												
		Glass melts (special glass)												
		Feeder and cooling (tempering)												
Chemical		Chemical and plastics industry												

Basis: No compensatory measures

Light radiator*, dark radiator*, warm air heater*: Here, "product quality" refers to space heating quality

No need for action
Partly some need for action
Need for action

, provide initial indications of sensitive and critical processes.



Sector		Process	Efficiency				Safety (emissions + thermal overload)				Product quality			
			Variation range Wobbe index / heating or calorific value to the set value											
			±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %	±2%	±4%	± 5.5 %	± 7.5 %
Heat-ing	Process	Light radiator*												
		Dark radiator*												
		Hot air generator*												
	Room	Heat and steam boilers												
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		Thermochemical heat treatment												
		Endogenous gas production												
		Galvanising processes												
		Melting processes (non-ferrous metals)												
		Lime kilns, calcination of clays												

Ceramics	Brick production												
	Porcelain firing												
Glass	Glass melts (container glass)												
	Glass melts (pane glass)												
	Glass melts (special glass)												
	Feeder and cooling (tempering)												
Chemical	Chemical and plastics industry												

Basis: No compensatory measures

Light radiator*, dark radiator*, warm air heater*: Here, "product quality" refers to space heating quality

No need for action
Partly some need for action
Need for action

Figure 9: Sensitivity of industrial combustion processes to natural gas quality fluctuations (independent of hydrogen admixtures) (Source: GWI et al. main study Gas Quality II)

In principle, it can be assumed that existing processes/plants in industry will require fundamental adaptation/revision when converting to 100 percent hydrogen. This may range from the replacement of the burner technology to the necessary I&C technology, or the replacement of refractory materials, all the way to a completely new installation. The (constant or fluctuating) admixture of up to 20 volume percent hydrogen is significantly more complex in terms of evaluation and must be considered in each individual case. The general rule here is that processes with a high air ratio can often be more robust with regard to the hydrogen admixture. The installation of comprehensive I&C technology can often be the basis for adapting existing processes and should therefore always be considered as a solution option.

The material use of natural gas is very challenging with regard to the admixture of hydrogen, as it is generally very sensitive to fluctuations in gas quality.

Relevant processes in the chemical industry include ammonia synthesis (e.g., for fertilizers), methanol synthesis, steam reforming (for syngas or hydrogen production), acetylene/ethyne/C_2H_2 production and the production of hydrocyanic acid (HCN). There are also processes such as endogas production, an application in metal processing (especially in hardening shops).

Background information (Source: DVGW Main Study Gas Quality Phase II, December 2018)

- A large proportion of domestic appliances and all industrial installations are set to a local gas quality that is usually unknown at the time of setting.

- The issue of gas quality is insufficiently focused on in many areas. Enquiries about gas compositions are relatively infrequent; the local Wobbe index is only enquired about annually or even less frequently in the domestic sector in over 90 percent of cases. In the industrial sector, only about 23 percent of end consumers have access to “real-time” data (i.e., data sources that provide data at least every 15 min).

- About 50 percent of the central energy supply plants (industrial power plants, large power plants) have automatic strategies in place that indirectly take into account the gas quality. Only about 7 percent of the respondents stated that they also use this in connection with gas quality fluctuations.

- Industrial and commercial plants are set at the plant optimum (near-stoichiometric operation, air ratio $\lambda \leq 1.15$) for reasons of efficiency; high requirements for emissions also apply. The focus is on maintaining product quality. 25 percent have compensation strategies, and a total of one third can react indirectly to gas quality fluctuations by regulating exhaust gas parameters.

- For the industrial and energy supply sectors, the Wobbe index plays only a subordinate role for the gas quality parameter. More important are the calorific value (Hi), the minimum air requirement (Lmin) or, for the material use of natural gas, the gas composition.

- Only a small but increasing proportion of domestic appliances and systems are equipped with gas-adaptive combustion control.

12.3 Further remarks on the technical analysis

12.3.1 Guidance on the network hydraulic hydrogen calculation with the STANET versions 10.1 and 10.2

General

There are various providers of network hydraulic calculation software. Typical analysis steps using the STANET provider will be shown below. Similar instructions for other providers are gladly included, to the extent that they are provided to H2vorOrt.

STANET is a network calculation and analysis system for the gas supply network and numerous other industries. An existing gas network model can be used to calculate hydrogen admixtures and hydrogen networks.

In the 10.1 version, calculations with different gas parameters were already possible, enabling hydrogen networks also to be calculated. In the new 10.2 release version (as at 02/2022), the calculation of the hydrogen admixture and hydrogen transport has been extended.

Version 10.1

Table 2: In Version 10.1, the following network parameters must be determined: density, compressibility factor and dynamic viscosity for natural gas, any mixing ratio of hydrogen and methane or 100 percent hydrogen.

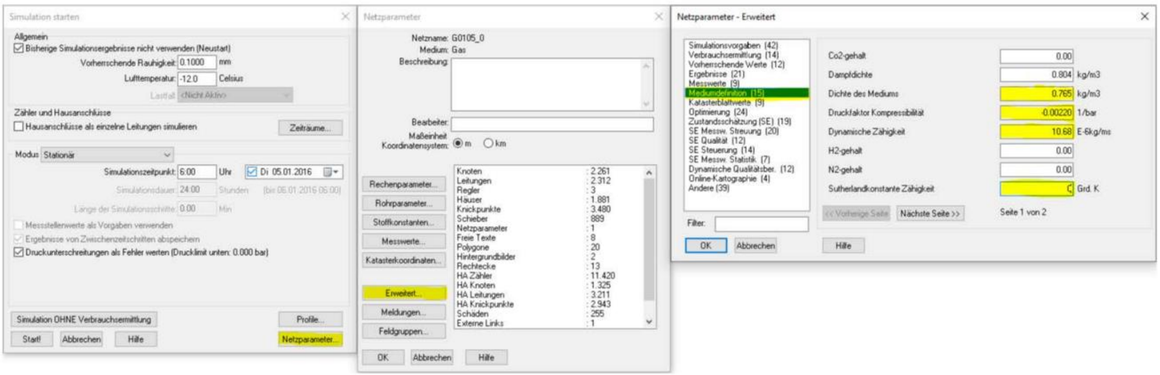
H_2 share	Density	Compressibility factor	Dynamic viscosity	Load factor	Note
Vol.-%	**kg/m³**	**1/bar**	*** 10-6 Pa*s**	**-**	**-**
0	0.765	-0.00252	10.68	1.0000	*Individual examination*
20	0.630	-0.00189	10.61	1.1591	*Individual calculation*
100	0.090	0.00059	8.48	3.1635	

The **load factor** corresponds to the ratio of the calorific value of natural gas to that of natural gas-hydrogen mixtures as a function of the hydrogen content (e.g., calorific value of natural gas: 11.2 kWh/m³; 100 percent hydrogen: 3.54 kWh/m³; Load factor: 11.2 kWh/m³/3.54 kWh/m³ = 3.16).

One-time settings:

Under 'Medium definition' (File → Network parameters → Advanced → Medium definition), the network parameters that have been determined: 'density of the medium', compressibility factor', 'dynamic viscosity', and 'Sutherland constant viscosity', must undergo a one-off adjustment. A **value of 0** must be entered in the '**Sutherland constant viscosity**' field.

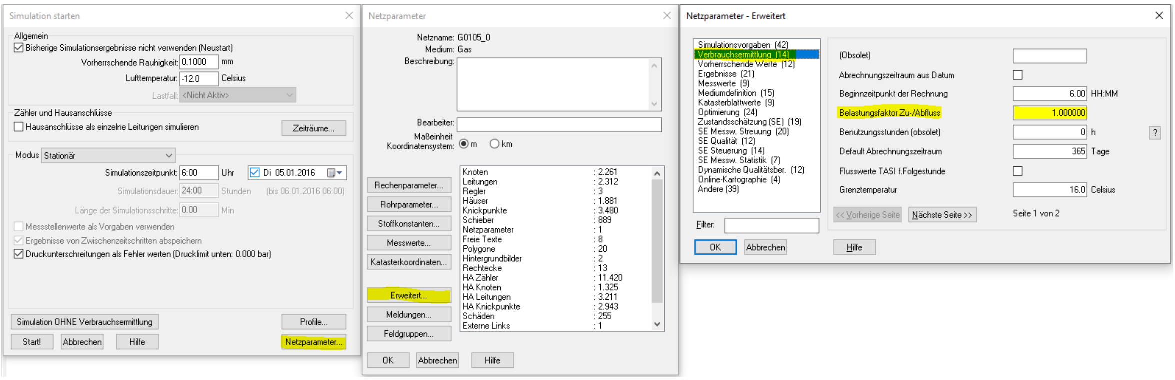
Failing this, STANET recalculates the viscosity according to the respective gas temperature from the dynamic viscosity entered, the gas temperature and the Sutherland constant.



Load factor setting

Under 'Determination of consumption' (File–> Network parameters -> Advanced -> Determination of consumption), the load factor must be entered.

Important note: the load factor must be re-entered before **every new calculation**, as the field automatically resets to 1,000,000 after the calculation!

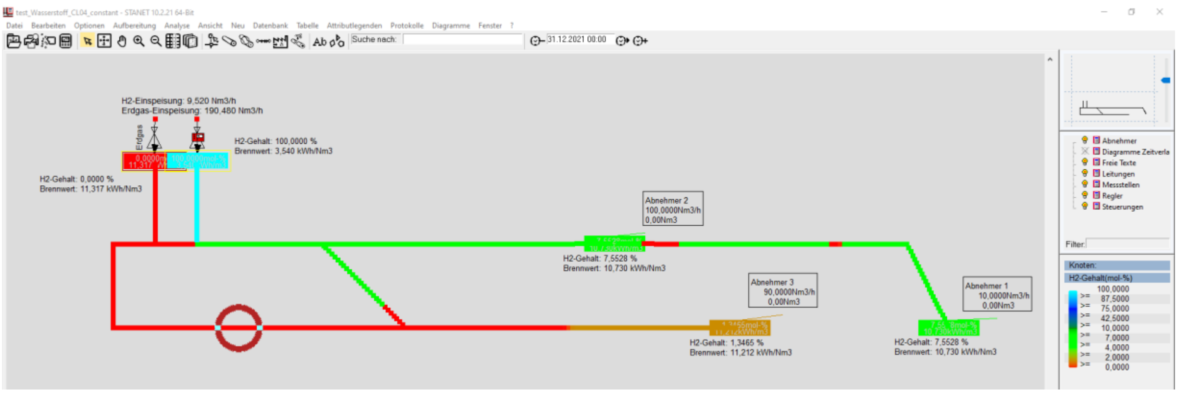


The calculation can be carried out.

Version 10.2

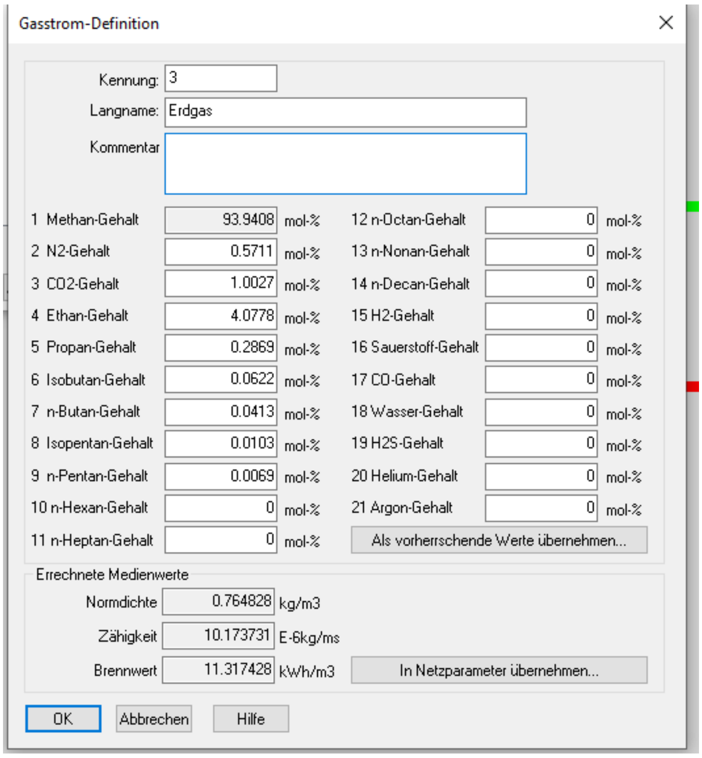
In Version 10.2, new functions for simulating gas networks were added that particularly address quality monitoring (gas composition, calorific value). This will take into account the challenge of increasingly distributed feed-in sources with different gas compositions being incorporated into the supply networks and a rising share of hydrogen being transported through the networks in the future.

The mixing of the various gas flows will be analyzed, both in the stationary case (gas composition at all network points at a steady-state flow) and the dynamic case (tracking the gas composition in the network by means of a simulation over a specific time period with varying offtakes/ feed-ins including network buffer).



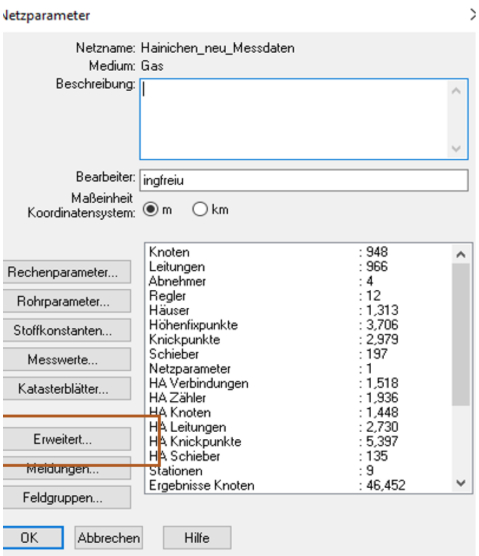
The calculation procedures according to GERG-2008 and AGA-8 for the characteristics of admixtures have been implemented, enabling the calculation and quality monitoring with up to 21 gas constituents.

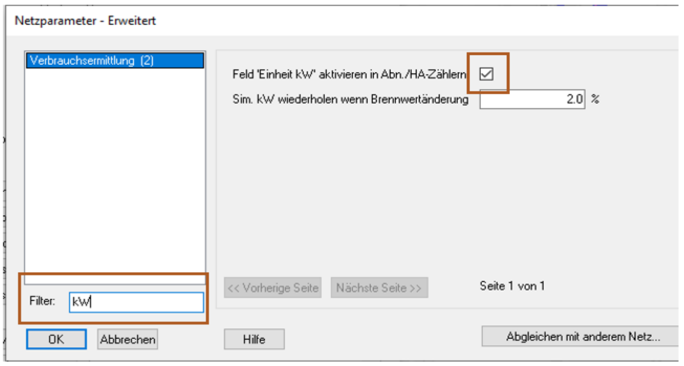
The gas composition is specified through gas flow definitions, which are allocated to feed-in nodes. The physical properties of standard density, viscosity, calorific value and compressibility of the admixtures will be automatically calculated by the program and can be transferred from the gas flow definition as well as prevailing values in the 'general network parameters' of a network model.



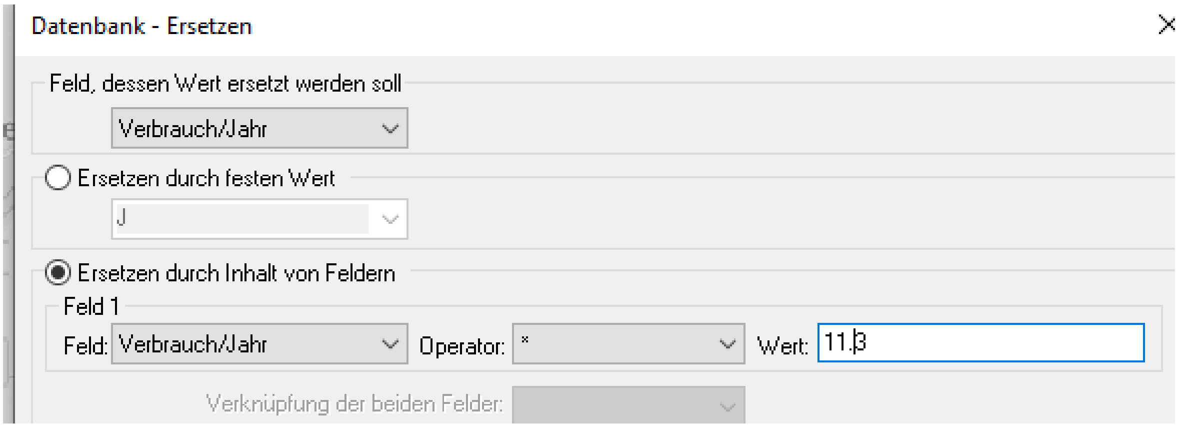
Conversion from m³/h to kWh

1) Under 'Consumption calculation' (File → Network parameters → Advanced → Consumption calculation), the 'Unit kW' must be activated.

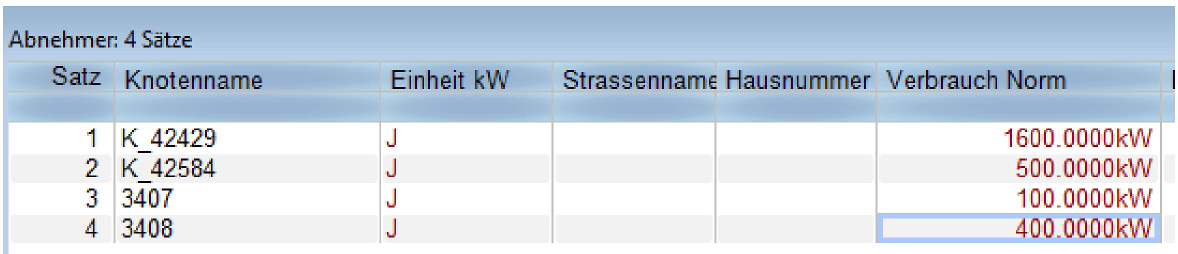




2) Under table → HA meter, the consumption per year in kWh is imported or converted to kWh through ‘Replace’.



3) Under table → HA meter/consumer: put ‘J’ in the field ‘Unit in kW’ and read in consumption standard in kWh, measured values in KWh:


Abnehmer: 4 Sätze

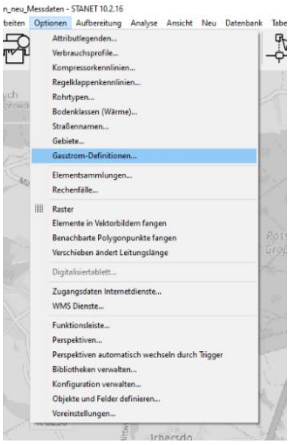
Satz	Knotenname	Einheit kW	Strassenname	Hausnummer	Verbrauch Norm
1	K_42429	J			1600.0000kW
2	K_42584	J			500.0000kW
3	3407	J			100.0000kW
4	3408	J			400.0000kW

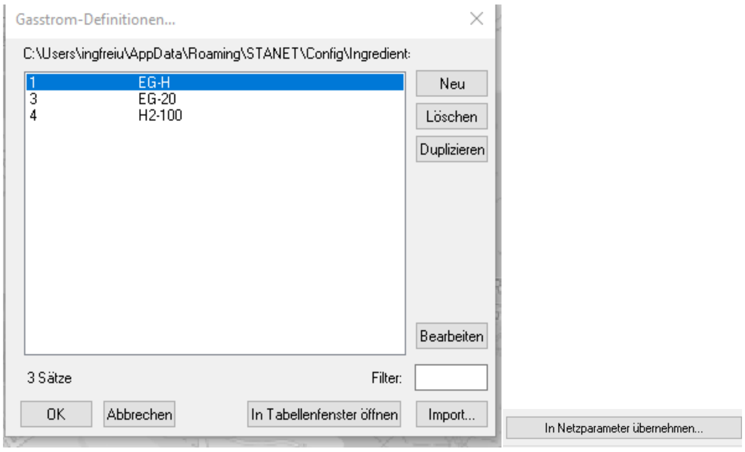
Setting K-factor formula

Under File → Network parameters → Calculation parameters, select the formula for calculating the K-factor. AGA 8 and GERG 2008 are available, among others.

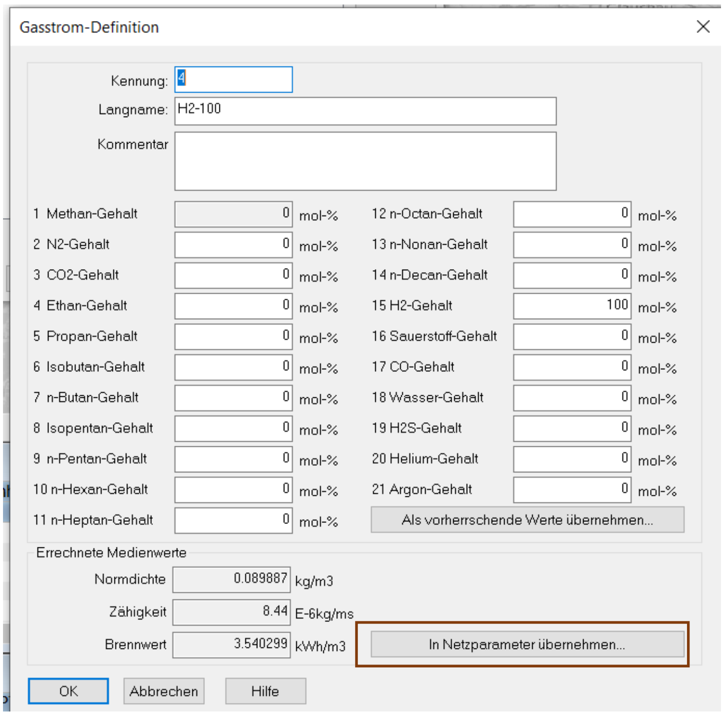
Dynamic quality tracking can be done under File → Network parameters → Advanced → Dynamic quality report. (e.g. -> activate D.Q. GERG2008).

Set gas flow definitions





Some definitions may already be created, others can be added. Apply the desired definition to the feed-in nodes or globally in the network parameters.



The substance data of the components are already stored in STANET.

Setting of further network parameters

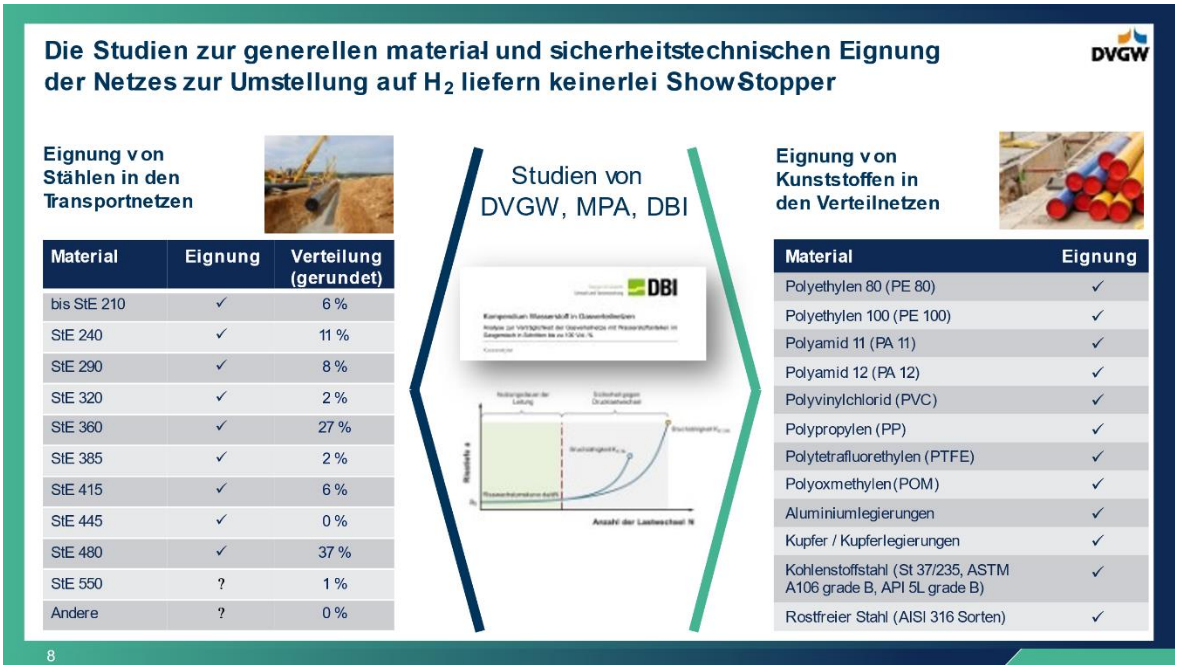
Some other settings must be selected in the network parameters such as:

- Calculate quality monitoring [J/N] (stationary) or calculate D.Q. qualities [J/N] (dynamic)
- Calculate quality cyclically with circular flow [J/N]

(Detailed descriptions can be found in the instruction manual).

The calculation can be carried out.

12.3.2 H_2 suitability of pipeline materials



The studies on general material and safety suitability of the networks to convert to H_2 reveal no obstacles

Suitability of steels in the transport network			Studies by DVGW, MPA, DBI	Suitability of plastics in the distribution networks	
Material	Suitability	Distribution (rounded off)		Material	Suitability
Up to SIE 210				Polyethylene 80 (PE 80)	
				Polyethylene 100 (PE 100)	
				Polyamide 11 (PA 11)	

				Polyamide 12 (PA 12)	
				Polyvinyl chloride (PVC)	
				Polypropylene (PP)	
				Polytetrafluorethylene (PTFE)	
				Aluminum alloys	
				Copper/ copper alloys	
				Carbon steel (St. 37/235, ASTM A106 grade B, API 5L grade B)	
				Stainless steel (AISI 316 types)	
Other					

Figure 8: Current state of knowledge regarding H_2 suitability of pipeline materials

12.3.2.1 Plastics

Pipes and moldings from the materials polyethylene PE63, PE80 und PE100, polyethylene with increased crack resistance PE100-RC, polyamide material PA-U12 (up to 16 bar) and other plastics (e.g., PVC) are suitable for distributing and transporting hydrogen up to 16 bar. Hydrogen-compatible PE-X pipes and fittings will be commercially made available for the application area of DVGW work sheet G 472.

Further details can be found in the DVGW fact sheet G 221.

12.3.2.2 Steel

Guidance on the hydrogen compatibility of steels for pipelines can be found in appendix C of the DVGW work sheet G 463

12.3.2.3 Ductile cast iron pipes & gray cast iron pipes

No final conclusion can presently be drawn regarding the H_2 suitability of cast iron pipes. Initial trials in the UK appear to be yielding positive results. However, this must be examined further.

12.3.2.4 Network buffer operation of high-pressure pipelines (> PN25)

For high-pressure gas pipelines operating as a network buffer with temporally varying operating pressures, an evaluation according to appendix C of the DVGW work sheet G 463 is to be applied.

12.3.2.5 Conversion of gas pipelines < 16 bar

Until the publication of the new DVGW fact sheets G 407 ‘Conversion from gas pipelines to steel pipes up to 16 bar operating pressure for the distribution of hydrogen-containing, methane-rich gases and hydrogen’ and G 408 ‘Conversion from gas pipelines from plastic pipes up to 16 bar operating pressure for the distribution of hydrogen-containing, methane-rich gases and hydrogen’, G 221 (M) shall be used for the conversion of gas pipelines < 16 bar.