Use of hydrogen in pipelines in Europe

Literature study

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Literature study: Use of hydrogen in pipelines in Europe

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Feedback

The consortium welcomes feedback. Please send your comments, suggestions or other feedback to the project coordinator, Dr. Adriaan van der Veen (VSL), avdveen@vsl.nl.

Contents

1 Introduction

This literature study related to the use of hydrogen in pipelines in Europe is part of the *European Partnership on Metrology* Project 21GRD05 Met4H2 Metrology for the hydrogen supply chain. This study focuses on the gas distribution grids, as well as any specific plans to use the grid to transport hydrogen in the form of gas at larger flow rates. The study also focused on relevant fiscal metering points and the demands for flow measurement technology. Outputs from 16NRM06 NEWGASMET and 20IND10 DECARB were included in the literature study.

2 Known, used and planned hydrogen distribution grids in Europe

2.1 Belgium

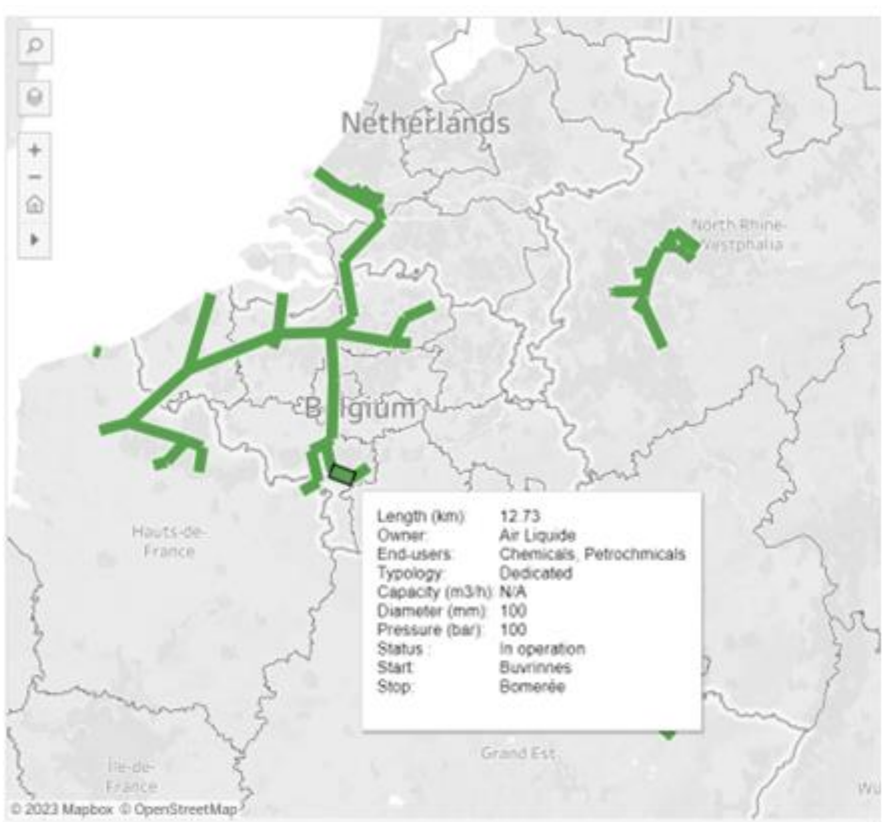

Figure 1: Hydrogen distribution networks located in Belgium

The website https://observatory.clean-hydrogen.europa.eu/ shows that the hydrogen distribution networks in Europe are mainly located in Belgium (Figure 1). The owner of these networks is the company Air Liquide [1]. In Belgium, the network is 964 km long and the end users are chemical and petrochemical companies.

2.2 Germany

The website https://observatory.clean-hydrogen.europa.eu/ shows that some others hydrogen distribution networks in Europe are located in Germany (Figure 2). The owners of these networks are companies Linde and Air Liquide [1]. In Germany, the network is 257 km long and the end users are chemical and petrochemical companies.

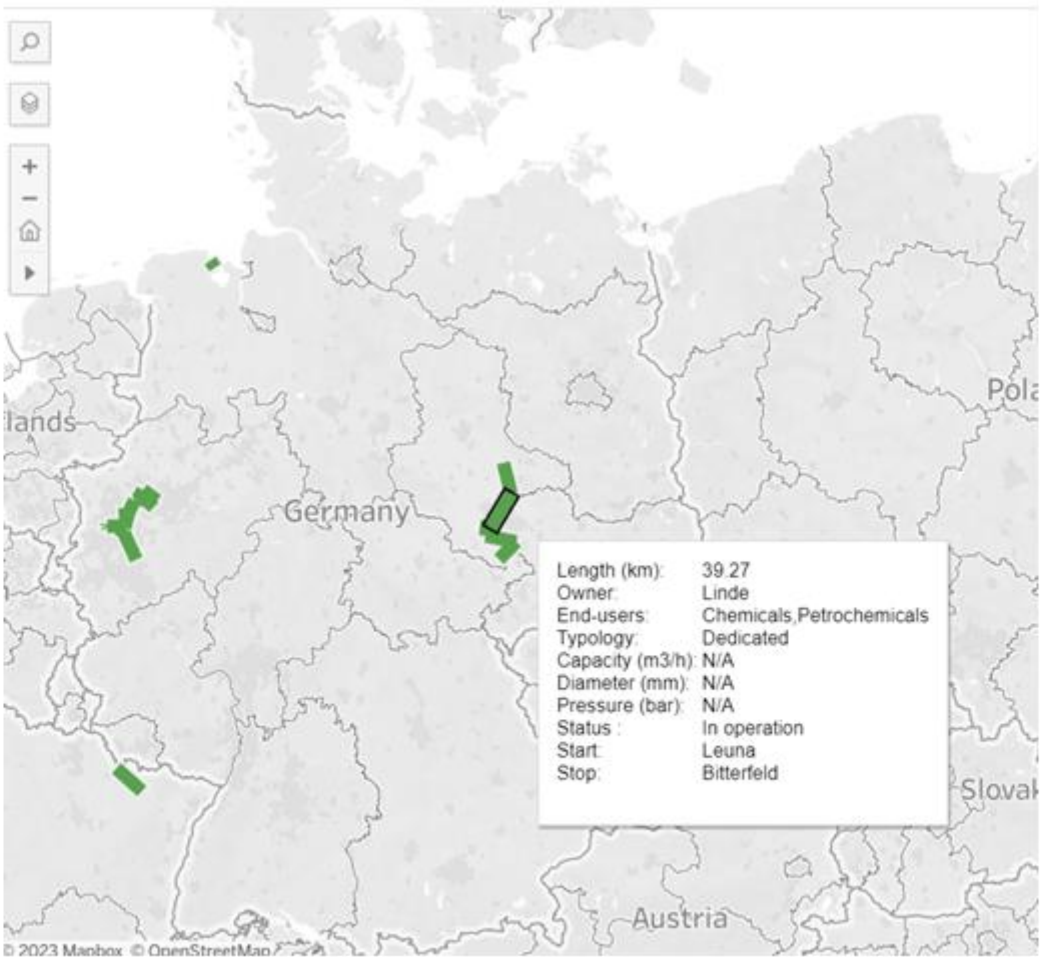

Figure 2: Hydrogen distribution networks located in Germany

The economic development agencies of Germany's northern states—Bremen, Hamburg, Mecklenburg-Vorpommern, Lower Saxony, and Schleswig-Holstein—have come together to launch HY-5, a joint initiative focused on promoting green hydrogen [2] (Figure 3). The new initiative aims to make Northern Germany the strongest European region for green hydrogen in a near future and to develop and complete the value chain for green hydrogen.

Figure 3: Initiative HY-5 in Germany

2.3 France

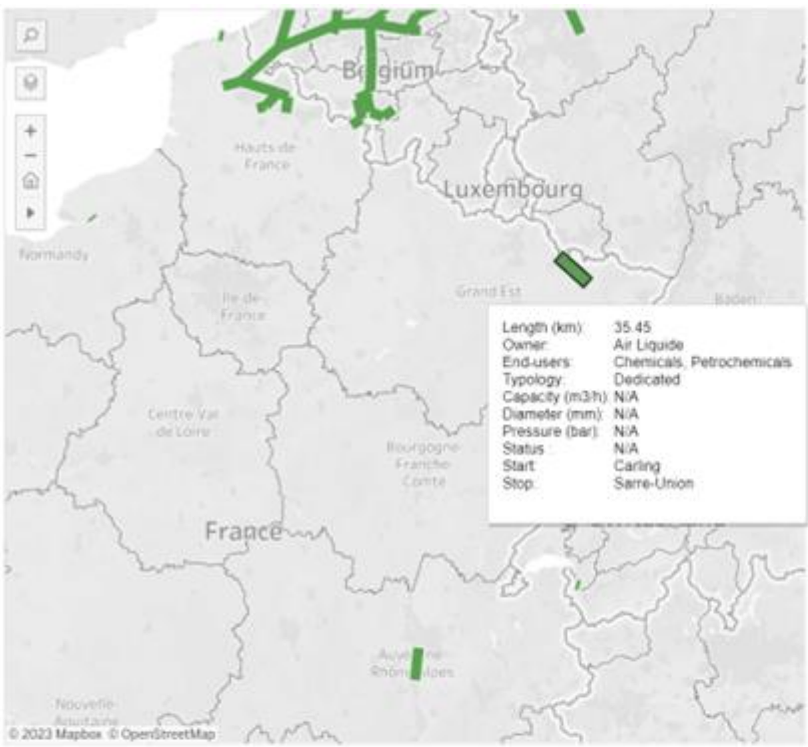

Figure 4: Hydrogen distribution networks located in France

The website https://observatory.clean-hydrogen.europa.eu/ shows other hydrogen distribution networks in Europe located in France (Figure 4). The owner of these networks is the company Air

Liquide [1]. In France, the network is 215 km long and the end users are chemical and petrochemical companies.

2.4 Netherlands

There is already a high-pressure pipeline (12 km) going from Dow Benelux to Yara. The hydrogen is a byproduct of Dow, used as feedstock at Yara. Companies Air Liquide and Air Products also operate hydrogen pipelines in the southwest of the Netherlands [1].

In many countries, discussions are only about mixing hydrogen in natural gas. This is not the case for the Netherlands. "Pure" hydrogen (>98 %) grids are expected here.

2.4.1 Distribution System Operators (DSO) grids and domestic hydrogen in the Netherlands

There is unfortunately no specification about use of gas meters in these projects. It can be supposed that some DSOs use existing domestic gas meters, typically diaphragm meters.

In the city of *Lochem* [3], there are 12 houses being fed with hydrogen as of December 2022. Tests will last 3 years. Houses got new boilers to run on hydrogen. The hydrogen is delivered using tube trailers but sent to the houses using existing grid pipelines.

Plans for a couple of hundred houses and DSO grid on hydrogen are mentioned here for the cities *Stad aan 't Haringvliet* [4] and *Rozenburg* [5]. In *Rozenburg,* two hydrogen boilers were installed in an apartment complex.

2.4.2 Transmission System Operator (TSO) in the Netherlands

The TSO of the Netherlands (*Gasunie*) is a stakeholder of the Met4H2 project. This TSO considers that traceability of hydrogen is a key area to develop. A subsidiary company of Gasunie (*Hynetwork Services*) was appointed by the government to realise a Dutch hydrogen gas network. The objective is to have it completed by 2030. It will connect the major industrial hubs/ports in the Netherlands. This will primarily be done using existing but also newly constructed infrastructure [6] [7].

2.4.3 HyDelta project(s)

HyDelta (https://hydelta.nl/) is a collaborative effort between public and private entities, functioning as a national research program in the Netherlands that supports the widescale deployment of hydrogen. The initiative makes its research findings publicly accessible. Its primary goal is to advance the hydrogen economy by addressing and overcoming scientific and technical challenges. One of the resulting papers focuses specifically on flow metering [8]. The main conclusions are:

- USM (Ultrasonic meters) and thermal mass are the most likely candidates for domestic gas metering.

- Changes from laminar to turbulent flow may occur in hydrogen gas metering, their impact on performance remains unknown.
- Impurities may have significant effects on thermal mass meters.
- Control installations (calibration facilities operated by DSO) need adaptation to be able to inspect hydrogen meters.
- The traceability chain is mostly non-existent.

2.5 Norway

There is a very small domestic gas distribution network in Norway and no plan to deploy such infrastructure in the nearby future; the domestic gas distribution grid is in a limited area in the coastal south-western part of the country with about 2500 customers [9]. The Norwegian gas grid is connecting gas fields and the three gas processing plants in Norway or gas terminals abroad (Germany, Belgium, France, United Kingdom) [10]. Thus, this study is focusing on current and future uses of this grid to transport hydrogen.

The Norwegian gas grid is operated by Gassco (state-owned) and owned by Gassled (joint venture) [10]. Figure 5 shows the current pipeline network on the Norwegian shelf.

There is a common ambition between Norway and Germany to develop infrastructures by 2030, notably a pipeline able to transport hydrogen and CO_2 [11]. So far hydrogen is produced in Norway by Yara (producing ammonia) and Equinor (producing methanol), as grey hydrogen, used directly on site. The current infrastructure allows to transport H_2 and could be used to transport blue H_2 to Germany, but not CO_2 back [12]. Due to high pressures in subsea pipelines, hydrogen embrittlement is more likely, and a lower pressure may be forced to limit this issue, impairing the transport capacity to about 30% of the one of natural gas [13]. Novel compressor technology specifically designed for hydrogen may be necessary to limit pressure drop along the pipe [13]. Also, ammonia tankers are an economically viable option for the transport of H_2 and may compete against pipelines [12] [13].

The objective of the H_2 connexion between Norway and Germany is paired with several other hydrogen-related objectives such as commissioning of electrolysers and development of infrastructures for ammonia distribution [14]. Technical feasibility is validated by Gassco and the *German Energy Agency* (DENA), with a need of qualified equipment such as flow meters, regulations, standards and guidelines (Figure 6) [15] [16]. Both options of using the current pipeline *Europipe 1* or relying entirely on a new network are considered in the final report from Gassco and DENA; the order of magnitude of the flow is in millions of tonnes per year [16]. The relevance of using the *Europipe 1* will depend on the needs of Germany on natural gas, as its use for hydrogen will reduce the natural gas distribution capacity from Norway to Germany by 20-25 %; however, a new terminal for hydrogen in Germany will be anyway necessary [16]. A target of 10 GW of blue hydrogen from Norway to Germany is set by Equinor and other stakeholders [17].

Research is ongoing to ensure the technical resistance and sustainability of pipelines [18]. Development of pipelines seems to be the best option compared to cables, with a ratio of 13 to 1 when comparing the potential of energy transport [19].

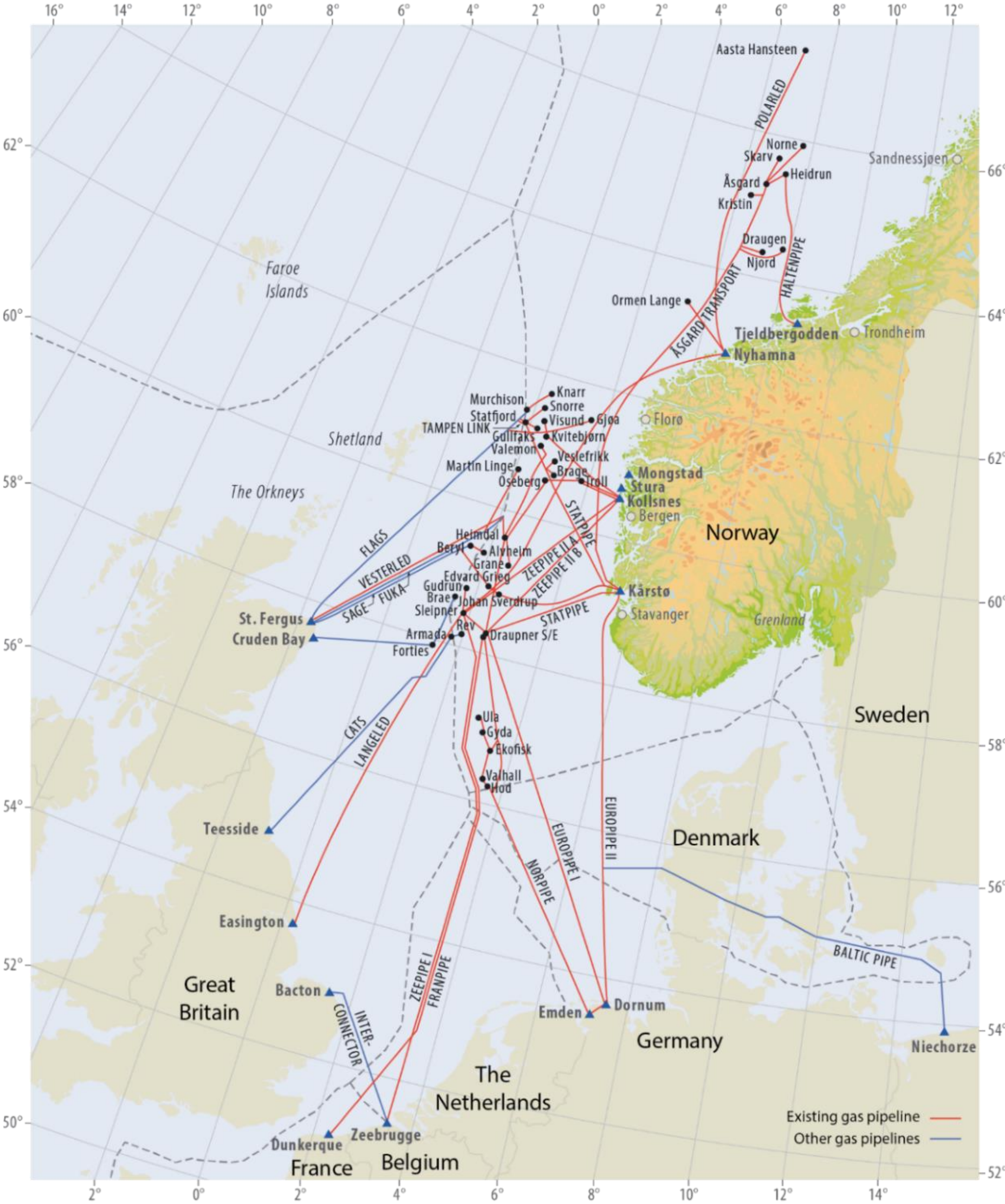

Figure 5: Map of gas grid in Norway. Taken from the websites of Norwegian Petroleum [10]. Interactive map available at Gassco's website. https://map.gassco.eu/map

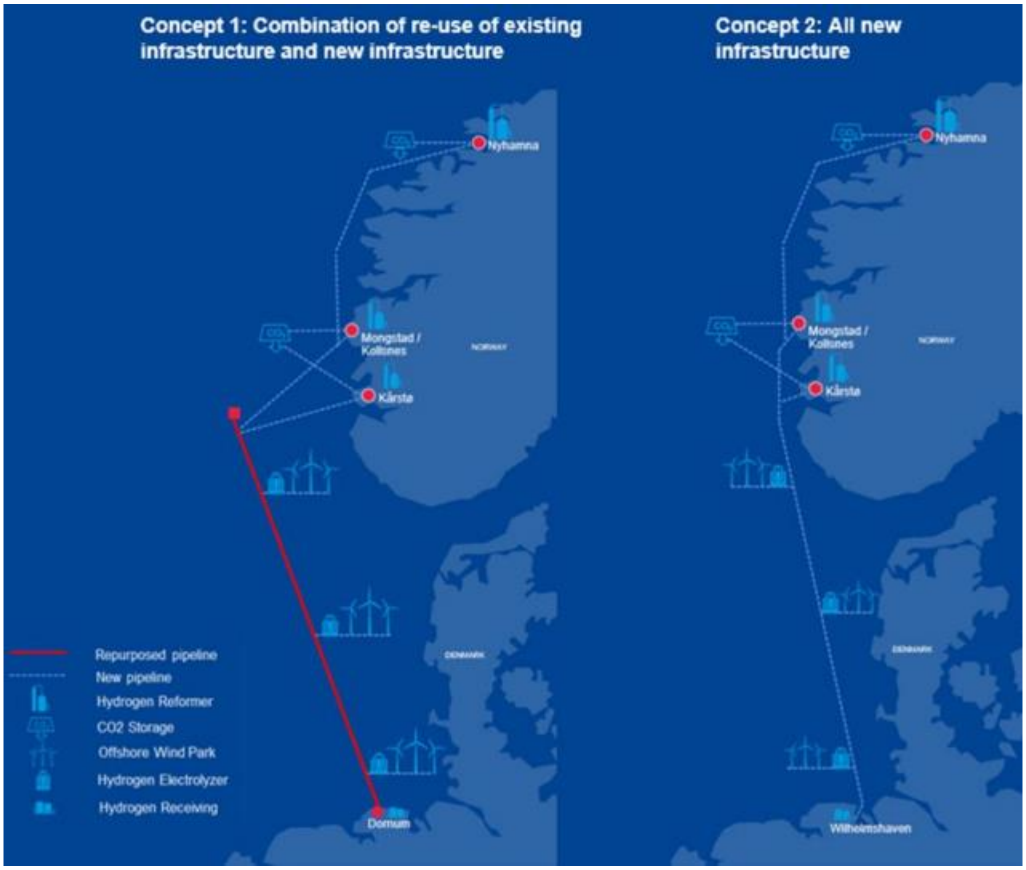

Figure 6: Offshore hydrogen transport concepts studied [16]

2.6 Denmark

A cooperation agreement was signed in March 2023 to establish hydrogen interconnectors to transport hydrogen made in Denmark (Figure 7) to German consumers. The plan covers deployment of 1,300 km of hydrogen pipelines up to 2045, as well as two dedicated hydrogen islands in the North Sea. The geological conditions in the North German lowlands are unique in Europe and ideally suited for the large-volume intermediate storage of hydrogen in caverns [20].

The first step toward establishing and operating the hydrogen infrastructure HySymbiosisNet has been taken. In 2023, a 0.5 km hydrogen pipeline was tested. One of the subsequent steps is to construct a 100 km long pipeline in 2026 [21]. The ClusterNortH2 project collaborates with Evida, Gas Storage Denmark, Eurowind Energy, and GreenLab. The completed pipeline is expected to be 170 km long, with a diameter of 12 inches and a pressure rating of 35 bar, facilitating the transportation of hydrogen throughout Northern Jutland (Figure 8) [22].

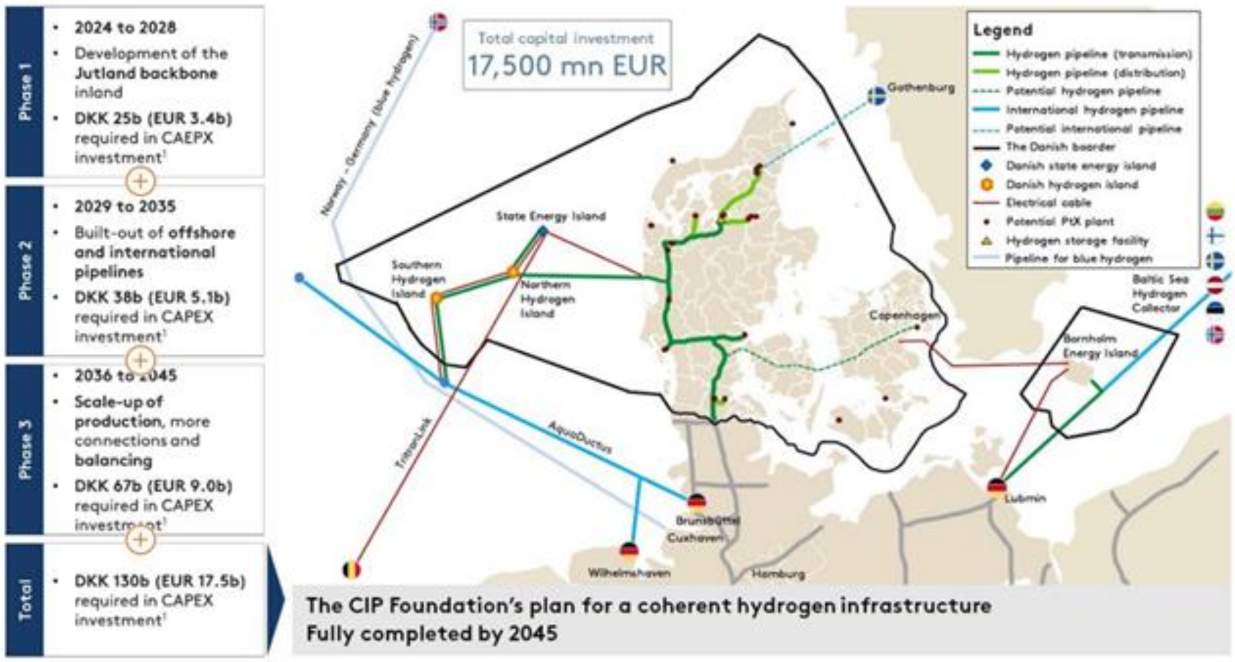

Figure 7: Hydrogen interconnection plans for transporting Danish hydrogen to German consumers.

Figure 8: The First plant hydrogen infrastructure in Denmark [22]

Energinet has announced plans to construct the West Jutland backbone, which will consist of a total pipeline length of approximately 360 km. The construction is scheduled to take place between 2025 and 2030, with a compressor station expected to be operational by 2038. To ensure future-proofing for the anticipated hydrogen market, an analysis indicates that the new pipes should be 36-inch in diameter, with a design pressure of 80 bar. Additionally, the existing natural gas pipeline in South Jutland, which currently has a diameter of 30 inches, could potentially be converted to accommodate hydrogen. The analyses suggest that there is no immediate capacity limitation (Figure 9) [23].

Figure 9: Hydrogen infrastructure in Denmark in 2030 [23]

There is also a website [24] that summarises plans for building hydrogen infrastructure in Denmark. Key topics on this web site include hydrogen quality and grid connection, system operation and balancing, and tariff design.

2.7 Czech Republic

There is so far no infrastructure in the Czech Republic where hydrogen is measured. The first commercial green hydrogen electrolyser in the Czech Republic was launched in 2023, with plans to launch more electrolysers in the coming years. This hydrogen will be consumed in cars or buses, or injected into the natural gas distribution network. For this case, two sites are being set up.

The most recent ambition of company EG.D, a.s. (DSO) is the Hype project (Hydrogen Project by E.ON Czech) in Mydlovary, which aims to build a production facility for green hydrogen in the South Bohemia region. The project will also include the construction of a test polygon where the effects of hydrogen on gas distribution system elements and metering will be investigated [25].

The company GASNET, s.r.o. (DSO) is planning two pilot projects in Aš-Trojmezí and Pardubice. 20 units of G4 gas meters (pure hydrogen and hydrogen-enriched natural gas), as well as rotary gas meters and operational safety are to be examined and tested in the long term [26].

2.8 United Kingdom

Although there is currently not a well-developed large-scale hydrogen pipeline in the United Kingdom (UK), based on the latest UK Hydrogen Strategy [27] published in August 2021, UK has plans to develop 'regional' or 'national' networks of hydrogen with large-scale storage sites, ideally by mid

2030s. Figure 10 shows Hydrogen Economy Roadmap of the UK. The figure has been taken from the UK Hydrogen Strategy document.

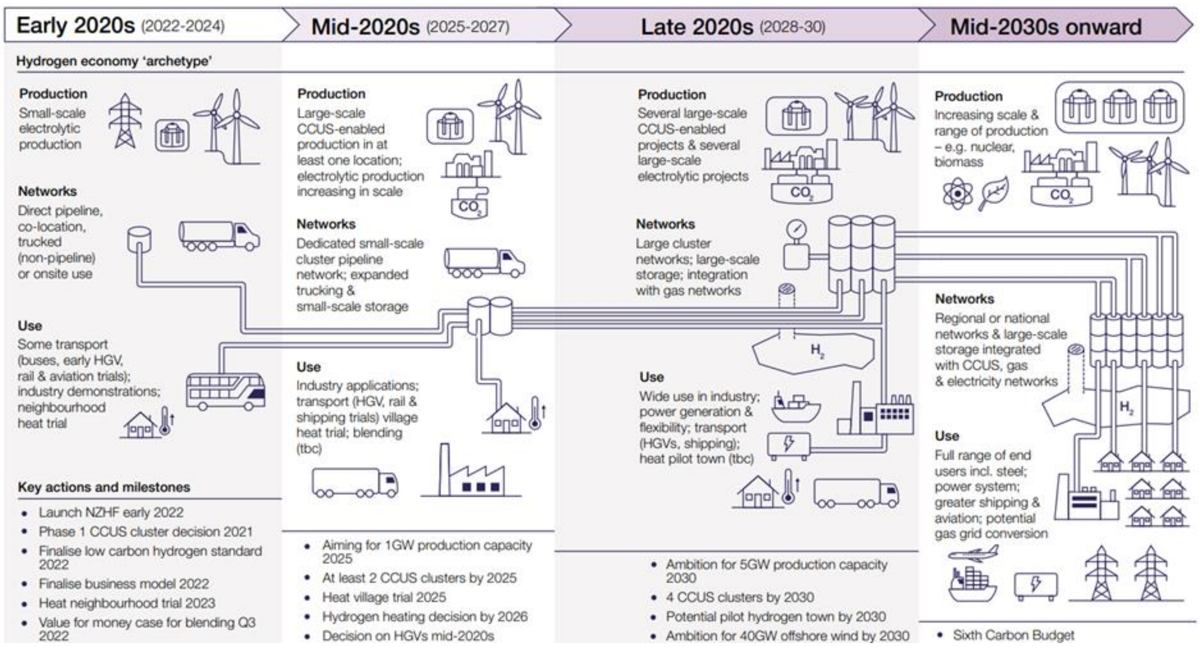

Figure 10: UK Hydrogen Roadmap (figure from UK Hydrogen Strategy, 2021 [27])

Making such a network will require the development of small and large-scale pipelines and flow measurement facilities that are suitable for hydrogen or hydrogen blends. UK is also investigating plans for the introduction of hydrogen into its existing natural gas network. Due to the complications that hydrogen can cause if it enters the gas network, the initial plan is to have a mixture of 20/80 percent of hydrogen/natural gas at the beginning and then to increase the percentage of hydrogen in increments, ideally up to 100%.

Another plan under investigation in the UK is to connect Scotland to the European Hydrogen Backbone (EHB) through a pipeline under the sea (Figure 11). This pipeline will be called Hydrogen Backbone Link (HBL) and will enable Scotland to export hydrogen to the European countries. The feasibility study of the development of HBL is now being undertaken by Net Zero Technology Centre (NZTC).

UK is also developing large scale test facilities for hydrogen. An example that is already developed and is currently operational is the Future Grid hydrogen test facility by National Gas.

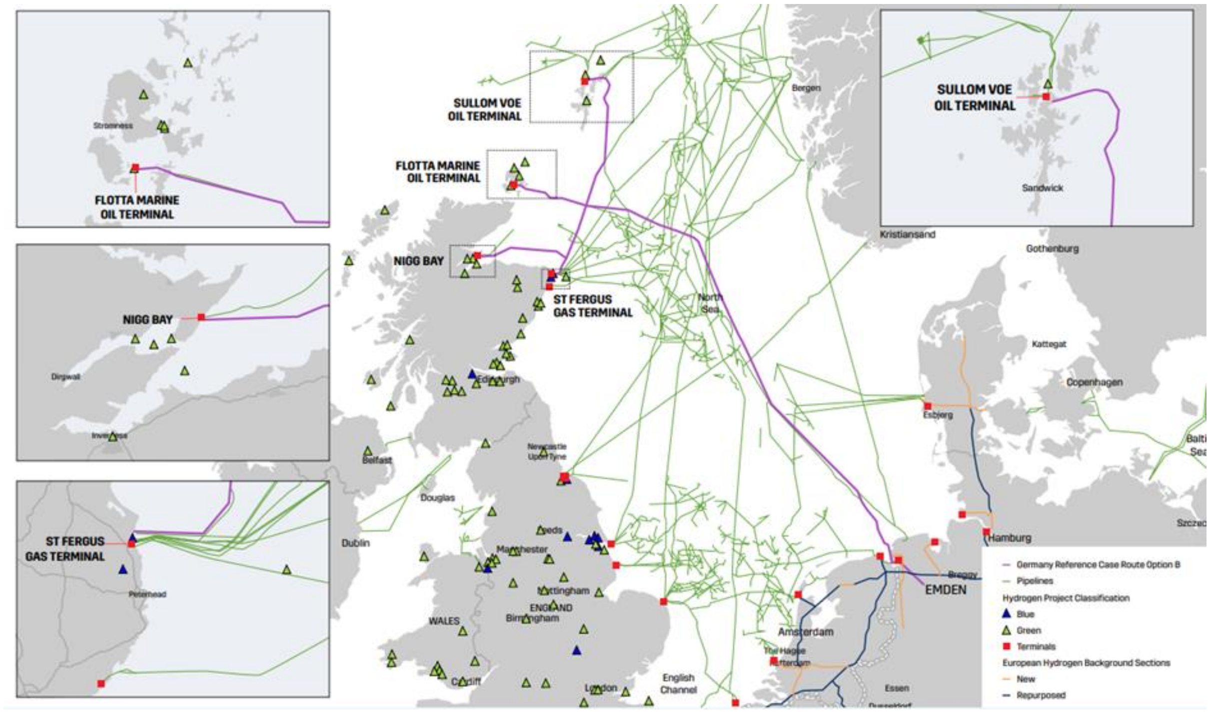

Figure 11: A possible route for the Hydrogen Backbone Link (Figure from the publicly available report of NZTC on Hydrogen backbone Link [28])

2.9 Italy

Figure 12 illustrates the existing hydrogen pipelines in Italy. They are located in Porto Marghera and Priolo Gargallo and owned by gas supplier companies (i.e., Air Products in and Air Liquide). These pipelines have limited lengths (1.63 km and 4.47 km, respectively) as they exclusively connect the hydrogen production sites to the end-users (i.e., chemical and petrochemical plants).

At present, the Decree of 3 June 2022 (Update to the Decree of the Minister of Economic Development of 18 May 2018, on: 'Technical regulation on the chemical and physical characteristics and presence of other components in fuel gas') sets the maximum blending concentration (i.e., the share of hydrogen in natural gas-hydrogen mixtures) to the 2% in volume. However, Snam Rete Gas (the national Transport System Operator-TSO) is committed to verify the compatibility of the existing network for the transport of natural gas-hydrogen mixtures with increasing percentages of hydrogen (up to 100%). Specifically, in April 2019, Snam Rete Gas began a verification process of its infrastructure by injecting a 5% hydrogen mixture into its natural gas transmission network in Contursi Terme (Salerno) with the aim of serving two local industries (a pasta factory and a mineral water bottling company) [29]. Furthermore, between 2019 and 2020, a second test was conducted in the same network segment exploring the injection of natural gas-hydrogen mixture with 10% of the hydrogen concentration [30]. In addition, in the framework of the National Recovery and Resilience Plan (PNRR), Snam is engaged in identifying the suitable locations to carry out the experiments required for updating the technical rules for the hydrogen transport in the gas network (Ministerial decree of 17 April 2008 and the Ministerial decree of 16 April 2008). SNAM is also evaluating the adoption of shared standard for hydrogen transport.

Figure 12: Hydrogen pipelines in Italy (modified from https://observatory.clean-hydrogen.europa.eu [1])

Figure 13: Italian hydrogen backbone [32]

Lastly, Snam is involved in the development of the Italian segment of the European Hydrogen Backbone (EHB). This pipeline will extend from the entry point in Sicily to the export points to Austria and Switzerland. This infrastructure could enable the transport of hydrogen produced in Northern Africa and Southern Italy to the main Italian and European consumption areas. As shown in Figure 13, the Italian Hydrogen Backbone will consist of around 2 300 km of pipelines (73% repurposed and 27% new built) and several compressor stations. With an import capacity of around 450 GWh/day from North Africa, this project is a major European corridor for renewable hydrogen import, serving Italian demand and with a capacity to export approximately 170 GWh/day to Austria and beyond [31].

2.10 Europe-wide distribution network

2.10.1 European Hydrogen Backbone

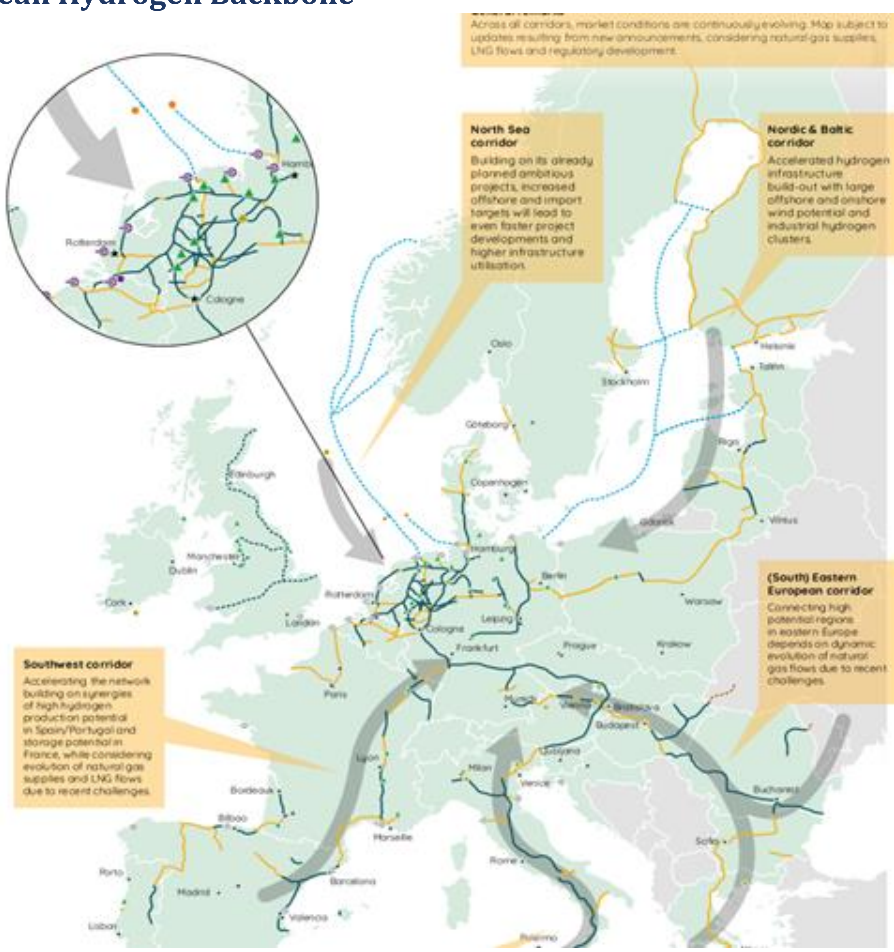

Figure 14: Plans of European Hydrogen Backbone

The initiative European Hydrogen Backbone (EHB) [33] was established in 2020. It is an initiative from a group of thirty-three energy infrastructure operators. By 2040, hydrogen infrastructure could evolve into a trans-European network spanning nearly 53,000 kilometers, primarily utilizing converted natural gas pipelines (see Figure 1).

According to the data presented, transporting hydrogen over a distance of 1,000 kilometers via a typical segment of the onshore hydrogen backbone would cost between €0.11 and €0.21 per kilogram of hydrogen, equivalent to €3.3 to €6.3 per MWh. If the hydrogen were instead transported entirely through purpose-built offshore subsea pipelines, the cost would rise to €0.17–€0.32 per kilogram (€4.5–€8.7 per MWh) for the same distance. These cost projections highlight that the European Hydrogen Backbone (EHB) represents a viable and economically efficient solution for long-range hydrogen transport, particularly when compared to a projected future production cost of €1.0–€2.0 per kilogram (€30–€60 per MWh). These cost estimates represent a weighted average across a wide range of pipeline sizes and types – ranging from repurposed 20-inch pipelines to new 48-inch ones – assuming a pressure range of 20 to 78 bar (Figure 15) [34] – and also reflect their respective distance and capacity-weighted shares within the context of the overall European Hydrogen Backbone.

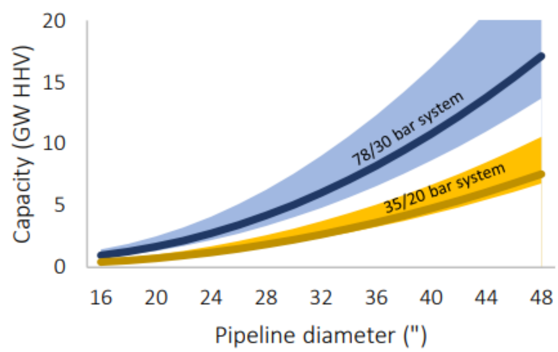

Figure 15: Transmission capacity in hydrogen pipes of various diameters. [34]

2.10.2 Central European Hydrogen Corridor

In September 2021, four major gas infrastructure operators from Central Europe formed a partnership aimed at establishing a hydrogen "highway" through the region [35]. This collaborative project, known as the Central European Hydrogen Corridor (CEHC), is designed to enable the transportation of hydrogen from Ukraine—an area with strong potential for large-scale green hydrogen production—through Slovakia and the Czech Republic, ultimately delivering it to key demand centers in Germany and across the European Union. Its total length is around 1,225 km (Figure 16).

On 28th of November 2023, the European Commission adopted a decision to put Central European Hydrogen Corridor (CEHC) on its list of projects of common interest (PCI) and mutual interest (PMI) with a generic status.

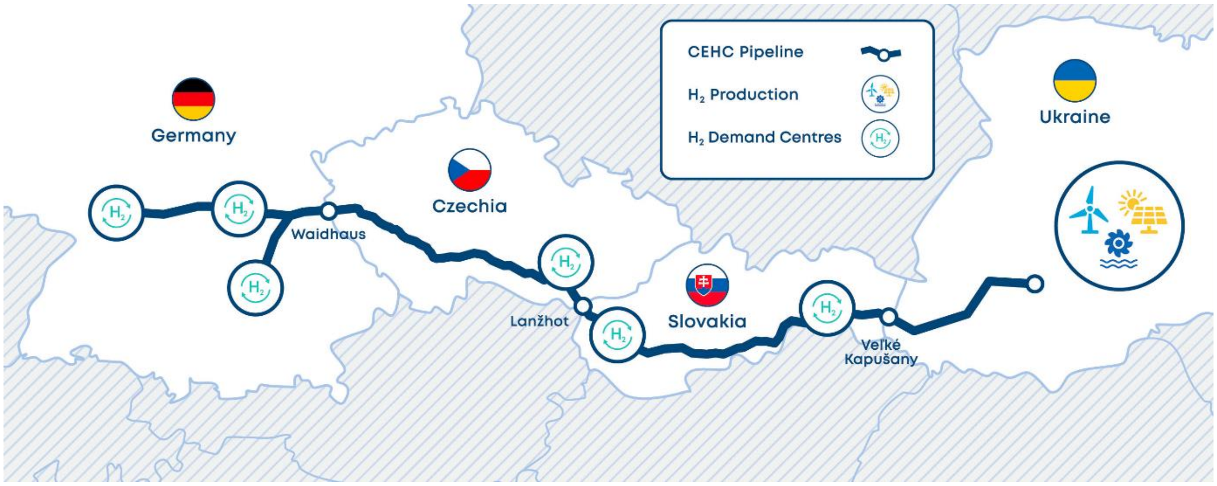

Figure 16: Central European Hydrogen Corridor

2.10.3 Project "Hydrogen in Gas Grids"

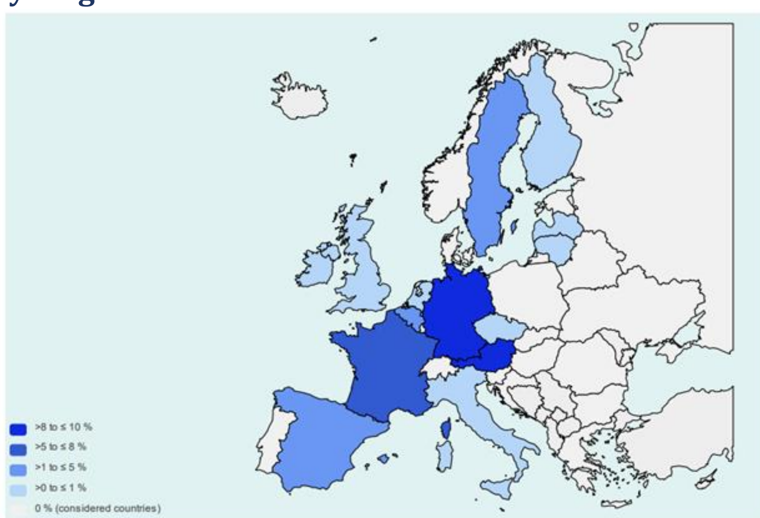

Figure 17: Allowed hydrogen concentration for blends with natural gas in the transit gas grids of the European countries [36]

The "Hydrogen in Gas Grids" (HIGGS) project [36] is dedicated to supporting the decarbonization of gas networks and their operation by addressing existing knowledge gaps regarding the effects of high hydrogen concentrations on gas infrastructure, its components, and overall system management. To achieve this objective, the project carries out a range of activities, such as identifying technical, legal, and regulatory challenges and opportunities, conducting testing and validation of systems and innovations, performing techno-economic modelling, and formulating a set of recommendations that serve as a roadmap for enabling hydrogen injection into high-pressure gas networks. During this project, a summary of hydrogen concentrations allowed in blends with natural gas in the transit gas grids of several European countries was created (Figure 17).

2.10.4 Project "H2med"

The H2med project has the ambition to interconnect Portugal, Spain, France and Germany with hydrogen pipelines. About 10% of the European hydrogen consumption could be transported using this corridor by 2030 (commissioning year). The pipelines CelZa (between Portugal and Spain) and BarMar (between Spain and France, offshore) are part of the network (dark green, Figure 18). The project relies on high renewable energy availability in Portugal and Spain [37].

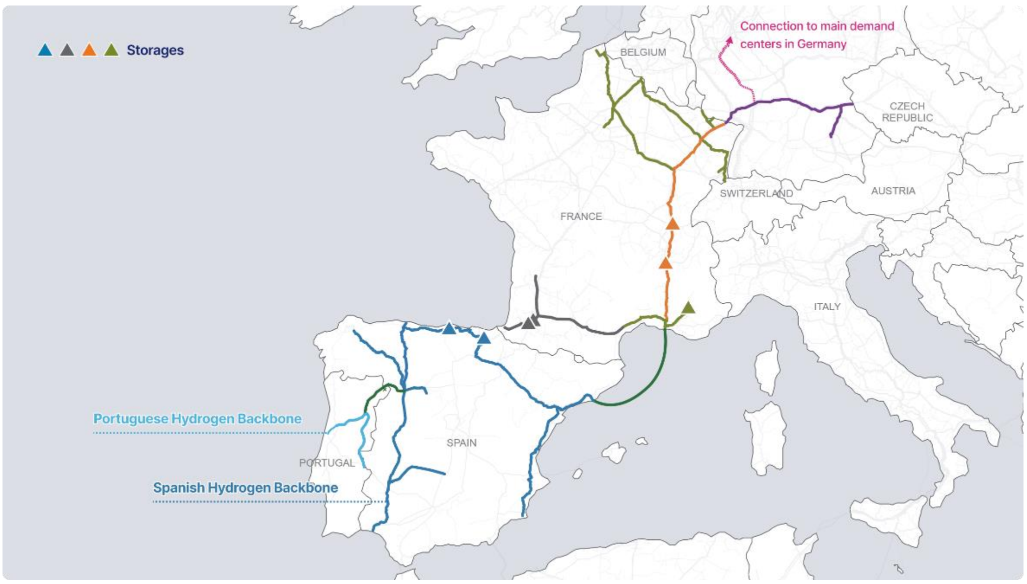

Figure 18: Routes of the pipelines within the H2Med project [37]

3 Suitability of using different gas flow meters for hydrogen measurement

3.1 Results of project 20IND10 DECARB (Metrology for decarbonising the gas grid)

In the report [38], techniques for hydrogen detection and determination of the percentage content of hydrogen in natural gas are mentioned. No results or recommendations are yet given in this project as to which instruments are suitable for measuring the flowing amount of hydrogen.

3.2 Results of project 18NRM06 NEWGASMET

The 18NRM06 NEWGASMET project [39] aims to enhance understanding of how accurate and durable commercially available gas meters remain when subjected to renewable gases such as biogas, biomethane, hydrogen, syngas and mixtures with natural gas.

During this project a static test with non-flowing hydrogen were performed with diaphragm gas meters, thermal mass gas meters and with domestic ultrasonic gas meters.

a. Summary of the results of diaphragm gas meters after durability tests with hydrogen

For the flow rates in the range of Q_t to Q_{max}, none of the differences in the errors after the durability test and the errors before the durability test exceed 2 %. All tested diaphragm gas meters were within tolerance of initial MPE for gas meters of accuracy class 1.5 before they were subjected to durability testing with hydrogen. The maximum difference was 0.52 %.

b. Summary of the results of thermal mass gas meters after durability tests with hydrogen

For the flow rates in the range of Q_t to Q_{max}, none of the differences in the errors after the durability test and the errors before the durability test exceed 2 %. A higher variation was noted in the error shifts of diaphragm gas meters. Prior to undergoing durability testing with hydrogen, all thermal mass gas meters tested remained within the original Maximum Permissible Error (MPE) limits for accuracy class 1.5 gas meters. After the hydrogen durability tests, all of these thermal mass meters still met the tolerance level, staying within twice the initial MPE defined for the same accuracy class. The maximum difference was 1.15 %.

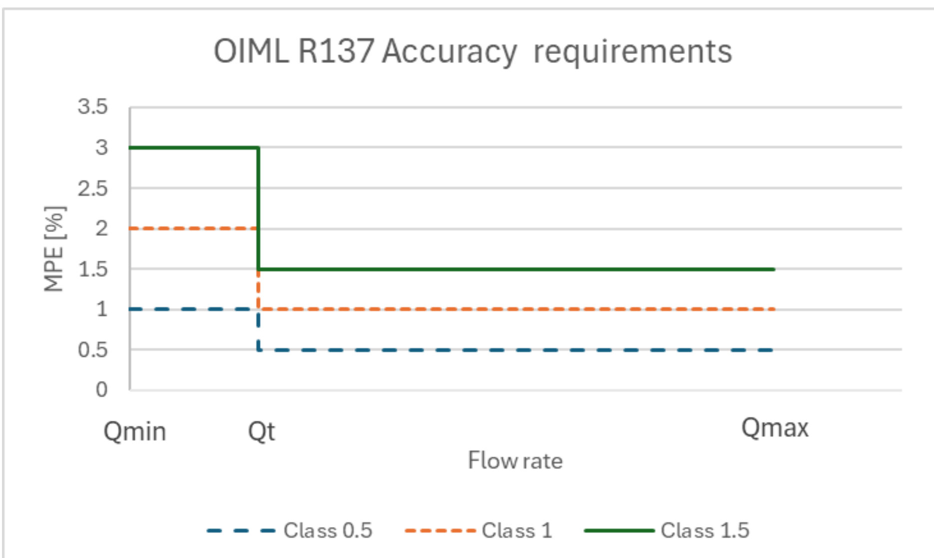

Figure 19: A summary of Maximum Permissible Error (MPE) as a function of flow rate (volumetric or mass), visualizing the different accuracy classes and the terms Q_{min}, Q_t and Q_{max}.

NEL and PTB developed calibration facilities with the required metrological quality according to OIML R137, this to carry out the accuracy tests required for conformity assessment of domestic gas meters with hydrogen or mixtures containing hydrogen. The uncertainty requirements for such tests given in OIML R137 (Figure 19) are fulfilled by the calibration facilities of both partners. From the calibrations using nitrogen and hydrogen, agreement between the results of PTB and NEL is acceptable for meters of Manufacturer B, even if there is no additional uncertainty influence by the meter shift considered. For all meters from both manufacturers there is no systematic difference when nitrogen and hydrogen is used as test gas. This statement is valid for diaphragm gas meter only, which can be understood from the fact that such a meter is based on a volumetric principle. Gas flow meters based on other operating principles must be investigated separately. Meters from Manufacturer A showed some differences between the results determined by the partners involved. These differences may be the result of damage to the meters during transport between the labs. Hence it is recommended to use meters selected for performance and do a very carefully packaging for such comparisons. In addition, shock sensors should be used to log mechanical stresses like severe shocks and vibrations.

When PTB calibrated the diaphragm meters with a wider range of test gases including methane and mixtures of hydrogen with methane, the permissible measurement deviations of ±3 % for $Q_{min} \le Q < Q_t$ and ±1.5 % for $Q_t \le Q < Q_{max}$ as required by EN 1359 were largely complied with. Whilst results differed for each test gas, there was no consistent trend towards positive or negative errors for any of the test gases. In summary, there was no overall tendency towards larger errors as hydrogen content in the test gases was increased.

For the thermal-mass domestic meter calibrated by NEL, there was a significant difference in the error curves for nitrogen and hydrogen. However, the metrological requirements of EN 17526:2021 for permissible errors, metrological stability, and gas-air relationship were achieved.

Using VSL's high-pressure Gas Oil Piston Prover primary standard (GOPP), the effect of mixing hydrogen with natural gas on the accuracy of a high-pressure flow meter was assessed for the first time. The accuracy of a G100 rotary flow meter was determined by direct calibration against primary reference values. The rotary flow meter was calibrated using both NG and HENG, at two different pressures: 9 bar and 16 bar. Although differences between errors with NG and HENG are mostly negative, these changes are insignificant from a metrological standpoint. The results show that, for the rotary flow meter and hydrogen blends containing less than 20 % H_2, the difference in meter error between calibration with high-pressure hydrogen mixtures and high-pressure natural gas is smaller than the difference observed between calibration with atmospheric pressure air and high-pressure natural gas.

3.3 DVGW project G202010 - Investigation of the behaviour of domestic gas meters in combination with house pressure regulators when using H_2 enriched gases

This project took place in the period 10.2020 - 08.2022 [40]. DVGW (Deutscher Verein des Gas- und Wasserfaches) together with PTB tested diaphragm gas meters. The tests were carried out with the fuel gases methane, methane with up to 30 % admixture of hydrogen as well as for pure hydrogen, as the Wobbe index for these gases is still within or slightly outside the limits of DVGW requirement. As no systematic gas type influence on the measurement and control behaviour were observed, the range above 30 % admixture of H_2 can also be regarded as metrologically safe. The analysed outlet pressure of the domestic pressure regulators shows that the gas type has no significant influence on the control quality. The results of the tests were within the limits specified by the relevant normative documents, which must be legally complied with in Germany, typically by the Measurement and Calibration Ordinance. Only minor differences were found between the error curves of the diaphragm gas meters when pressurised with the various gases or gas mixtures during the metrological investigation. The household pressure regulators have no influence on the measurement deviation of the diaphragm gas meters. The calibration and adjustment for conformity assessment of pressure regulators and diaphragm gas meters, which are intended for measuring H_2 natural gas mixtures or pure hydrogen, can be carried out using air as the test gas. This means that there are no additional production costs. The gas meters analysed in this project were as good as new devices whose error curves were accordingly within the calibration error limits and which show the lowest possible absolute error values in the entire flow range as a result of the adjustment.

3.4 Domestic Gas Meter Durability in Hydrogen and Natural Gas Mixtures

The *Oil and Gas Institute - National Research Institute* in Poland and *Department of Civil and Mechanical Engineering, University of Cassino and South Lazio* in Italy tested diaphragm and thermal mass gas meters for durability with hydrogen-enriched natural gas [41]. The experiments were conducted using 2E natural gas as well as blends of natural gas with hydrogen added at volume concentrations of 5 percent, 10 percent, and 15 percent. These tests were performed over durations of 5000 hours and 10000 hours. In some cases, diaphragm gas meters were examined for as long as 15000 hours, while testing of thermal gas meters concluded after 7500 hours. The main conclusions drawn from the results are presented below [54]:

- For all samples tested for durability, including both new gas meters and those that had been in operation for ten years, the presence of hydrogen in the gas mixture did not produce a significant metrological effect on the average drift in measurement error observed after testing. An exception was noted in one Type 1 gas meter from the 2E H0 sample group (without hydrogen), where internal leakage likely occurred. Aside from this case, all meters fulfilled the metrological standards for durability tests as specified by the EN 1359 standard.
- In most instances, neither diaphragm gas meters nor thermal gas meters exhibited any statistically significant change in error due to the presence of hydrogen in the gas after being subjected to long-term testing. However, for new Type 4 diaphragm meters and in-service Type 7 meters, statistically significant differences in the average drift of indication errors were found after 10000 hours of testing when comparing meters exposed to a 2E gas mixture with 15 percent hydrogen to those tested with pure 2E gas. These differences were identified at flow rates of 0.4 times Qmax, 0.7 times Qmax, three times Qmin, and Qmax. Nevertheless, a comparison of the average error drift for the control group 2E H0 and the test group 2E H15 shows that the observed variations are smaller than the uncertainty of determining such differences, meaning they should not be considered metrologically significant.
- After 10000 hours of durability testing, no meaningful difference in the average change in weighted mean error was identified across the tested gas mixtures for any meter type. Nearly all measurement errors stayed within a range of plus or minus 1.2 percent, except for four outliers among the 105 tested meters.

- No mechanical failures were discovered during the tests that could jeopardize operational safety. All the gas meters, whether diaphragm type or thermal type, remained leak-proof and structurally intact throughout the testing period.
- The results of tests on diaphragm gas meters, both new and previously used, as well as thermal gas meters, indicate that these devices can be employed for billing purposes when measuring natural gas containing up to 15 percent hydrogen by volume. However, it is important to emphasize that continued research in flow metrology is necessary, since the results apply only to a specific selection of gas meters and do not represent all designs currently in use.

3.5 Declarations from manufactures of gas meters

Companies Apator Metrix S.A., ELEKTROMETAL S.A., Elster GmbH, Dresser Utility Solutions GmbH, MeteRSit have stated that a large number of their gas meters (diaphragm, thermal mass, rotary piston gas meters) are capable of measuring natural gas with hydrogen content or pure hydrogen. For higher flow rates and higher pressures, ultrasonic gas meters can be used. Several manufacturers such as RMG Messtechnik GmbH, KROHNE Messtechnik GmbH, SICK AG and others declare that their ultrasonic gas meters are capable of measuring the flowing amount of hydrogen or hydrogen-enriched natural gas.

4 Normative documents

Since developing modern standards for complex technologies often takes years, it is important to quickly create and follow a clear plan with set priorities. Developing these standards on time is key to keeping them aligned with both new technologies and current laws and regulations. That is why *European Clean Hydrogen Alliance (ECH2A)* [42] and *CEN* issued ROADMAP ON HYDROGEN STANDARDISATION [43].

Physikalisch Technische Bundesanstalt (Germany) issued *Technical Guidelines for Measuring instruments for Gas* **G 19** [44] which states that:

In principle, there are no objections to the use of gas meters of any technology approved for natural gas for the measurement of hydrogen-enriched natural gases with substance quantity fractions $x_{H2} \leq 5$ %. Use of these meters up to $x_{H2} = 10$ % is permitted if the manufacturer explicitly authorises this in the relevant documentation (e.g. operating manual). Use above $x_{H2} = 10$ % is only permitted with a corresponding manufacturer's declaration and a clearance certificate from the PTB.

5 Conclusion

This literature study has covered the use of hydrogen in gas pipelines in Europe, including both the gas distribution network and any specific plans to use the network to transport hydrogen. The study highlights that a lot of countries in Europe are taking part in developing a well-connected hydrogen pipeline network. The network could potentially start from Norway and Finland, extends through the sea to Germany, and continues all the way to Italy, with the possibility of further extension to Greece. Secondly, the North Sea is expected to have a great influence on green energy production, particularly in the context of green hydrogen. This influence extends to countries such as Denmark, Norway, the Netherlands, Belgium, Germany, Great Britain, and France. Thirdly, in Central Europe, a CEHC pipeline is planned to transport hydrogen from Ukraine to Germany, crossing Czechia and Slovakia. Overall, this network could span 53,000 kilometres with expected pipes from 20 to 48-inch in diameter, with a design pressure of 80 bar, and serve as a backbone for European hydrogen infrastructure. It has made use of material provided by participants in the project *21GRD05 Metrology for the hydrogen supply chain* (Met4H2) project.

In general, this is a new and emerging industry and energy sector, and so the data collected on actual use and long-term experience for each type of meter used for hydrogen measurement is not extensive. From the data obtained, it can be expected that diaphragm gas meters would be used to measure hydrogen and its mixture with natural gas for smaller flow rates, up to approximately 16 m^3/h, and that they have performed slightly better than thermal mass gas meters. For higher flow rates, up to approximately 400 m^3/h, rotary gas meters will probably be used, and ultrasonic gas meters for even higher flow rates. For higher pressures, Coriolis flow meters could be an option, although there is little research so far done on these flow meters.

References

[1] Initiative by the Clean Hydrogen Joint Undertaking, the European Hydrogen Observatory

https://observatory.clean-hydrogen.europa.eu/index.php/tools-reports/geomap

[2] Green Hydrogen Initiative HY-5 in Northern Germany

https://www.hy-5.org/en/welcome/

[3] Lochem - pilot project -12 homes running on hydrogen in the Netherlands

https://www.lochem.nl/afval-energie-natuur-en-milieu/energie/waterstofgas

https://www.alliander.com/nl/energietransitie/pilots-met-waterstof/lochem/

https://www.alliander.com/content/uploads/dotcom/Rapportage-waterstofpilot-Lochem-2022-2023_Definitief.pdf

[4] Project City Natural Gas Free in *Stad aan het haringvliet* in the Netherlands

https://www.stedin.net/over-stedin/duurzaamheid-en-innovaties/waterstof/stad-aardgasvrij

[5] Heating project with two hydrogen boilers in city *Rozenburg* in the Netherlands

https://www.stedin.net/over-stedin/duurzaamheid-en-innovaties/een-nieuw-energiesysteem/power2gas

https://www.stedin.net/-/media/project/online/files/projecten/factsheet-power2gas.pdf

[6] Gasunie - Hydrogen in the energy transition in the Netherlands

https://www.gasunie.nl/expertise/waterstof/gasunie-en-waterstof

[7] Creating a national hydrogen network in the Netherlands

https://www.hynetwork.nl/en

[8]: HyDelta - Hydrogen flow metering for the built environment in the Netherlands

https://zenodo.org/records/6424111#.Yk_i4zWxWUk

https://zenodo.org/records/6424111/files/D1D_1_HyDelta_Eerste_Tranche_Gas_meters_NL.pdf?download=1

[9] "Norway Natural Gas Security Policy," IEA, 11 10 2022. [Online]. Available: https://www.iea.org/articles/norway-natural-gas-security-policy

[10] "The oil and gas pipeline system," Norwegian Petroleum, 11 08 2023. [Online]. Available: https://www.norskpetroleum.no/en/production-and-exports/the-oil-and-gas-pipeline-system/

[11] "Joint Statement - Germany – Norway - Hydrogen," Ministry of Petroleum and Energy, 1 5 2023. [Online].

https://www.regjeringen.no/en/whatsnew/dep/smk/press-releases/2023/closer-cooperation-between-norway-and-germany-to-develop-green-industry/joint-statement-germany-norway-hydrogen/id2958105/

[12] C.S.W. Cheng, "Does time matter? A multi-level assessment of delayed energy transitions and hydrogen pathways in Norway," Energy Research & Social Science, vol. 100, 2023.

[13] C.S.W. Cheng, "The prospects of green and blue hydrogen production in Norway for energy export," University of Stavanger, 2020.

[14] H. Risnes, "The first week of the new year is now over, and what a week it was!," Arena H2Cluster, 10 01 2023. Available: https://h2cluster.com/news/amazing-start-to-2023-in-hydrogen-norway

[15] C. Currie, "Norway-Germany hydrogen pipeline is 'technically feasible', DENA-Gassco study finds," 28 11 2023. [Online]. Available: https://www.h2-view.com/story/norway-germany-hydrogen-pipeline-is-technically-feasible-dena-gassco-study-finds/2102845.article/

[16] K. M. Lakeit, "German-Norwegian Energy Cooperation Joint Feasibility Study," 2023.

[17] "Hydrogen pipeline in the North Sea," RWE, 2023. Available: https://www.rwe.com/en/research-and-development/project-plans/hydrogen-pipeline-in-the-north-sea/

[18] "Safe Pipelines for Hydrogen Transport," The Research Council of Norway, Available: https://prosjektbanken.forskningsradet.no/en/project/FORISS/294739.

[19] N. Røkke, "Hydrogen in our time," HYDROGENi, 26 1 2023. Available: https://hydrogeni.no/news/hydrogen-in-our-time/

[20] CIP Fonden Newsletter , September 2023

[21] De første brintrør til Power-to-X er lagt i Jorden//The first hydrogen pipes for Power-to-X have been laid in the ground, GreenLab, Linda Fejerskov, April 2024

https://www.greenlab.dk/knowledge/foerste-spadestik-hysymbiosisnet/

[22] ClusterNortH2 De første skridt til brintinfrastruktur i Midt- og Nordjylland // The first steps towards hydrogen infrastructure in Central and North Jutland, ClusterNortH2, March 2022.

https://www.greenlab.dk/media/1427/clusternorth2-final-rapport.pdf

[23] Feasibility studie brinttransmissionsinfrastruktur i jylland// Feasibility study hydrogen transmission infrastructure in Jutland, Energinet, page 4, August 2023.

https://energinet.dk/media/3g2htdyf/energinet-feasibility-rapport-2023.pdf

[24] Establishing and operating the Danish hydrogen infrastructure

https://en.energinet.dk/hydrogen/

[25] Hype Project (Hydrogen Project by E.ON Czech)

https://www.hytep.cz/en/platform/platform-members/associated-members/eg-d-a-s https://www.eon.cz/byznys-energie/vodiku-verime/

[26] GASNET Pilot projects with hydrogen

https://m.cirihk.cz/files/prezentace_konference_2023/5.-humhal-frantisek-gasnet-prezentace.pdf

[27] HM Government, "UK hydrogen strategy," OGL, 2021.

[28] Net Zero Technology Centre, "hydrogen Backbone Link," NZTC, 2022.

[29] Snam: Europe's first supply of hydrogen and natural gas blend into transmission network to industrial users

https://www.snam.it/en/media/news-and-press-releases/comunicati-stampa/2019/snam-europe-s-first-supply-of-hydrogen-and-natural-gas-blend-into-transmission-network-to-industrial-users.html

[30] Snam: hydrogen blend doubled to 10% in Contursi trial

https://www.snam.it/en/media/news-and-press-releases/news/2020/snam-hydrogen-blend-doubled-to-10--in-contursi-trial.html

[31] General description of the SouthH2 Corridor

https://www.south2corridor.net/south2

[32] Snam Rete Gas – Schede di intervento, page 117

https://www.snam.it/export/sites/snam-rp/repository-srg/file/it/business-servizi/Processi_Online/Allacciamenti/informazioni/piano-decennale/pd_2022_2031/consultazione/01.-Allegato-Schede-di-Intervento.pdf

[33] European Hydrogen Backbone (EHB)

https://ehb.eu/

[34] System perspective analysis 2022 pathways towards a robust future energy system, Energinet, page 27, January 2022.

https://energinet.dk/media/y5rhoqjy/pathways-towards-a-robust-future-energy-system_energinet-2023-01-23.pdf

[35] Central European Hydrogen Corridor

https://www.cehc.eu/

[36] Hydrogen in Gas Grids (HIGGS) project

https://higgsproject.eu/

[37] The H2med project, Supplying Europe with affordable carbon-free energy.

https://h2medproject.com/the-h2med-project/

[38] Gundolf Weseloh (PTB), Dirk Tuma (BAM), Bert Anders (PTB), Report A2.3.2: A brief survey about the available techniques for fast online measurement of hydrogen in natural gas

https://www.decarbgrid.eu/app/uploads/sites/19/2023/09/EMPIR-Decarb-Report-A2.3.2-M13-final.pdf

[39] Project 18NRM06 NEWGASMET

https://newgasmet.eu/

[40] DVGW project G202010 - Investigation of the behaviour of domestic gas meters in combination with house pressure regulators when using H_2 enriched gases.

https://www.dvgw.de/themen/forschung-und-innovation/forschungsprojekte/dvgw-forschungsprojekt-h2-messrichtigkeit

[41] Jaworski, J.; Kułaga, P.; Ficco, G.; Dell'Isola, M. Domestic Gas Meter Durability in Hydrogen and Natural Gas Mixtures. Energies 2021, 14, 7555.

https://www.mdpi.com/1996-1073/14/22/7555

https://www.mdpi.com/1996-1073/14/22/7555/pdf?version=1636711425

[42] European Clean Hydrogen Alliance (ECH2A)

https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance_en

[43] ROADMAP ON HYDROGEN STANDARDISATION, March 2023

https://www.cencenelec.eu/media/CEN-CENELEC/News/Press%20Releases/2023/20230301_ech2a_roadmaphydrogenstandardisation.pdf

[44] Technische Richtlinien Physikalisch-Technische Bundesanstalt, G 19 Wasserstoff im Gasnetz (Edition: 02/23)

https://oar.ptb.de/files/download/510.20221017B.pdf