European Hydrogen Backbone

A EUROPEAN HYDROGEN INFRASTRUCTURE VISION COVERING 28 COUNTRIES

APRIL 2022

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Executive summary

Since its founding in 2020, the European Hydrogen Backbone (EHB) initiative has contributed to the development of a European hydrogen market through the publications of its flagship EHB maps, with a vision of a pan-European hydrogen transport infrastructure. These network maps demonstrate how this vision is both technically feasible and economically affordable. The role of hydrogen in enabling climate neutrality is widely acknowledged, as is the need for hydrogen pipeline transport in the future European energy system. Recently, the essential role for hydrogen pipeline infrastructure in fostering market competition, security of supply, and security of demand was recognised in the European Commission's hydrogen and decarbonised gas package, published in December 2021.[1]

Following the invasion of Ukraine by Russia, the impetus for a rapid clean energy transition has never been stronger. This position was firmly established in the European Commission's REPowerEU proposal, a plan to phase out Europe's dependence on fossil fuels from Russia well before 2030 and to increase the resilience of the EU-wide energy system. Amongst other measures, REPowerEU introduces an ambition to reach an additional 15 million tonnes (Mt) of renewable hydrogen on top of the 5.6 Mt foreseen under Fit for 55, going beyond the targets of the EU's hydrogen strategy.[2] Achieving these targets will require a rapid acceleration of the development of an integrated gas and hydrogen infrastructure, hydrogen storage facilities, and port infrastructure.

In light of the EC's REPowerEU proposal and in response to accelerated hydrogen market developments, this report presents an updated, extended, and accelerated EHB vision, now involving 31 energy infrastructure companies from 28 countries. The updated hydrogen infrastructure network maps as presented in this report build on the EHB initiative's prior body of work. The accelerated vision shows that by 2030, five pan-European hydrogen supply and import corridors could emerge, connecting industrial clusters, ports, and hydrogen valleys to regions of abundant hydrogen supply — and supporting the EC's ambition to promote the development of a 20.6 Mt renewable and low-carbon hydrogen market in Europe.[3] The hydrogen infrastructure can then grow to become a pan-European network, with a length of almost 53,000 km by 2040, largely based on repurposed existing natural gas infrastructure.[4] Moreover, the maps show possible additional routes that could emerge, including potential offshore interconnectors and pipelines in regions outside the area where the EHB members are active. A 'live' version of the maps presented in this report can also be found in digital format on the EHB initiative's website, which will be launched shortly after this report in April 2022.[5]

The European Hydrogen Backbone for 2040 as proposed in this report requires an estimated total investment of €80-143 billion. This investment cost estimate, which is relatively limited in the overall context of the European energy transition, includes subsea pipelines and interconnectors linking countries to offshore energy hubs and potential export regions. Transporting hydrogen over 1,000 km along the proposed onshore backbone would on average cost €0.11-0.21 per kg of hydrogen, making the EHB the most cost-effective option for large-scale, long-distance hydrogen transport. In case hydrogen is transported exclusively via subsea pipelines, the cost would be €0.17-0.32 per kg of hydrogen per 1,000 km transported.

1 European Commission (2021) – Proposal for a recast Directive / Regulation on gas markets and hydrogen (COM(2021) 803 final) / (COM(2021) 804 final). Source: https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/hydrogen-and-decarbonised-gas-market-package_en

2 European Commission (2022) – REPowerEU: Joint European Action for more affordable, secure, and sustainable energy (COM(2022) 109 final). Source: https://energy.ec.europa.eu/repowereu-joint-european-action-more-affordable-secure-and-sustainable-energy_en

3 According to REPowerEU, the additional 15 Mt (compared to 5.6 Mt foreseen in Fit for 55) would be made of 10 Mt of imported hydrogen from diverse sources and an additional 5 Mt of hydrogen produced in Europe.

4 The share of repurposed natural gas pipelines in 2040 would be over 60%.

5 https://www.ehb.eu/maps

European climate protection, energy system resilience, and security of supply are interlinked more than ever before. The European Hydrogen Backbone creates an opportunity to accelerate decarbonisation of the energy sector by efficiently integrating substantial volumes of additional renewable and low-carbon energy and by connecting regions with abundant supply potential with centres of demand. Moreover, the EHB has the potential to revitalise Europe's industrial economy whilst ensuring energy system resilience, increased energy independence, and security of supply across Europe. Such a vision can be achieved in a cost-effective manner, but it requires close collaboration between EU Member States and neighbouring countries and a stable, supportive, and adaptive regulatory framework.

To achieve the EC's ambitious Fit for 55 and REPowerEU goals, and to foster an accelerated development of the European Hydrogen Backbone, this paper presents the following levers to facilitate implementation of infrastructure projects.

The EHB recommends introducing in the REPowerEU plan the establishment of import corridors, including all infrastructure requirements, as a political objective.

- Establish a more integrated energy system planning of hydrogen, natural gas, and electricity infrastructure at EU and Member State level.
- Promote efficient measures to facilitate the swift development of a dedicated hydrogen infrastructure by fostering repurposing of existing natural gas infrastructure.
- Simplify and shorten planning and permitting procedures for renewable energy and hydrogen projects.
- Unlock financing to fast-track hydrogen infrastructure deployment by leveraging funding mechanisms such as the Connecting Europe Facility (CEF), Important Projects of Common European Interest (IPCEI) and Horizon Europe funds.
- Encourage international cooperation and create intra and extra-European energy and hydrogen partnerships.

The EHB initiative is looking forward to discussing its vision with stakeholders including policy makers, companies, and initiatives along the hydrogen value chain.

In Figure 1 the accelerated and updated 2030 EHB network, which supports the EC's REPowerEU ambition, is shown.

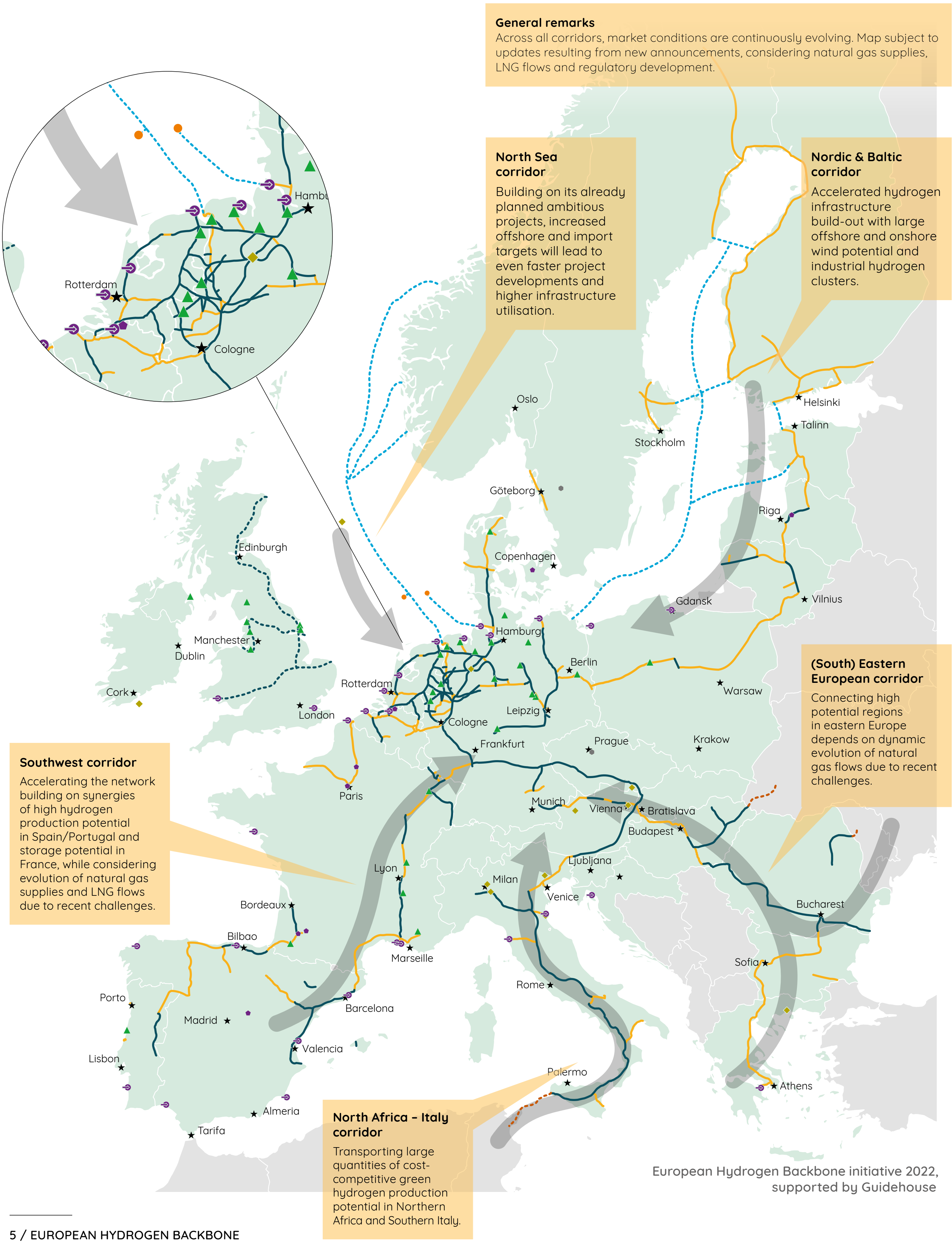
Figure 1 – 2030

Accelerated and updated 2030 EHB network supports the EC's REPowerEU ambition to create a domestic and import market for hydrogen and increase European energy system resilience

Pipelines
- Repurposed
- New
- Subsea
- Import / Export
- UK 2030 pipelines depends on pending selection of hydrogen clusters

Storages
- Salt cavern
- Aquifer
- Depleted field
- Rock cavern

Other
- City, for orientation purposes
- Energy hub / Offshore (wind) hydrogen production
- Existing or planned gas-import-terminal



1. Introduction

The European Hydrogen Backbone (EHB) initiative is a group of European energy infrastructure operators which initially published a vision paper for a dedicated hydrogen pipeline infrastructure, to a large extent based on repurposed natural gas pipelines in July 2020, with maps covering nine EU Member States plus Switzerland, home to the eleven Transmission System Operators (TSOs) participating at that time. Since then, the EHB initiative has grown to 31 European network operators with infrastructure covering 25 EU Member States plus Norway, the United Kingdom, and Switzerland. This report contains a geographically extended vision for a dedicated hydrogen infrastructure stretching across these 28 European countries.

Following the release of the initial vision network, market participants across the hydrogen value chain have engaged and signalled interest in the EHB initiative's work. Market feedback frequently concerned the as yet long time periods required to realise the envisaged vision network. In view of accelerated national and European climate ambitions, first-mover market actors have called for the need to accelerate hydrogen infrastructure planning and development to support feasibility, security, and affordability of their energy transition strategies.

In addition, the invasion of Ukraine by Russia in February 2022 has made a strong and clear case for a rapid clean energy transition. In the face of these events, the European Commission published REPowerEU,[6] a plan to phase out Russian fossil fuel imports well before 2030 and to increase the resilience of the European energy system. The plan aims to diversify gas supplies and speed up the roll-out of renewable gases and hydrogen in Europe, setting a goal to reach an additional 15 million tonnes (Mt) of renewable hydrogen — 5 Mt domestically produced, and 10 Mt imported — on top of the 5.6 Mt foreseen under Fit for 55, going beyond the targets of the EU's hydrogen strategy.

In response to accelerated market developments and a Europe-wide strategic need to increase energy system security through hydrogen, this EHB report presents an updated vision of the growing initiative, with hydrogen infrastructure maps for 2030 and 2040:

- The geographical expansion of the EHB maps is reflective of the EU's accelerating climate ambitions and the heightened interest in a pan-European hydrogen network, as indicated in the European Commission's Fit for 55 and hydrogen and decarbonised gas packages, respectively.[7]
- The updated pan-European hydrogen network map for 2030 is aligned to the EC's ambition to develop a 20.6 Mt renewable and low-carbon hydrogen market in Europe, as presented in the REPowerEU proposal.
- The vision maps indicate possible future locations of underground hydrogen storage.[8] These storage locations are indicative and do not yet consider the concurrent need for methane and hydrogen storage nor the fact that new underground storage sites could be developed. The amount of storage that would be required in the future depends on several factors and is not further analysed in this paper.
- The maps and results presented in this report can also be found in digital format on the EHB initiative's website, launched jointly with this report.[9]

The suggested pathway for the creation of a dedicated hydrogen backbone infrastructure is informed by studies commissioned by the Gas for Climate consortium in 2019 and 2020, and by the EHB initiative in 2021, which showed a large future role for hydrogen in a decarbonised European energy system and a gradually declining role for natural gas, partially replaced by biomethane. The network vision presented in this report builds on the body of work undertaken by the EHB initiative in previous years, national hydrogen strategies and planning processes as well as an evaluation of announced projects on hydrogen supply and demand across Europe and neighbouring countries that are potentially able to export hydrogen.

6 European Commission (2022) – REPowerEU: Joint European Action for more affordable, secure, and sustainable energy (COM(2022) 109 final). Source: https://energy.ec.europa.eu/repowereu-joint-european-action-more-affordable-secure-and-sustainable-energy_en
7 European Commission (2021) – Proposal for a recast Directive / Regulation on gas markets and hydrogen (COM(2021) 803 final) / (COM(2021) 804 final). Source: https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/hydrogen-and-decarbonised-gas-market-package_en
8 Gas Infrastructure Europe (2021) – Picturing the value of gas storage to the European hydrogen system. Source: https://www.gie.eu/gie-presents-new-study-picturing-the-value-of-underground-gas-storage-to-the-european-hydrogen-system/
9 https://www.ehb.eu/maps

The European Hydrogen Backbone vision starts from the current status quo yet assumes a high ambition level for future climate change policies. Nonetheless, it is important to note that the eventual infrastructure solution will be highly dependent on future supply and demand dynamics of the integrated energy system, including natural gas, hydrogen, electricity, and heat. The real development of hydrogen supply and demand and the increasing integration of the energy system may lead to alternative or additional routes compared to the ones described in this paper, and the timeline of some of the 2030 and 2040 proposed routes may be shifted forward or backward in time. The timelines for the scale up of hydrogen can vary from country to country, reflecting national energy policy discussions and the status of hydrogen investment projects as well as the rate of renewable energy developments. Across Europe, the speed with which dedicated hydrogen transport infrastructure can be created depends on market conditions for natural gas and hydrogen, political support to stimulate hydrogen production and demand, and regulatory frameworks for hydrogen transport.

The aforementioned energy market, policy, and regulatory drivers are subject to even more volatility as a result of the ongoing war in Ukraine. Although this report considers and welcomes the need to accelerate hydrogen developments in view of geopolitical events, it also acknowledges that the corresponding level of disruption to energy and gas markets and infrastructure are and will continue to be multi-faceted, unpredictable, and variable over time. The role of LNG, biomethane, alternative pipeline gas, and hydrogen volumes, including all connected infrastructure, are closely interlinked and their uncertainty – especially in the short and medium-term – implies that infrastructure planning must be done in a manner that is responsive and resilient to different potential future scenarios. For this reason, the network maps and infrastructure proposals in this publication are accompanied, where possible, by call-out boxes indicating key uncertainties, identified by the TSOs, that have the potential to affect the infrastructure proposals as shown.

The next chapter presents updated 2030 and 2040 EHB maps, including a description of their developments and impact. The final chapter describes acceleration levers that can help to promote rapid roll-out of the EHB and support the EC's goals as described in their REPowerEU plan.

The EHB initiative has grown to 31 European network operators with infrastructure covering 25 EU Member States plus Norway, the United Kingdom, and Switzerland.

2. Gradual creation of a dedicated hydrogen infrastructure to increase the resilience of the European energy system

2.1. Acceleration of hydrogen infrastructure to enable the emergence of pan-European supply and import corridors by 2030

The European Commission's REPowerEU plan aims to reach an additional 15 Mt of hydrogen on top of the 5.6 Mt foreseen under Fit for 55.[10] The total expected volume of 20.6 Mt by 2030 will likely consist of a range of supply sources including, amongst other options: co-located (demand-side) electrolysis; centralised hydrogen production from captive renewable energy sources; large-scale blue hydrogen production; pipeline imports; and ship imports of hydrogen derivatives such as ammonia and methanol. Depending on their use case, these volumes will require varying degrees of transport infrastructure to connect supply regions to demand.

Previous EHB analysis has shown that a hydrogen pipeline can transport some 65 TWh of hydrogen per year.[11] **For perspective, this means that transporting half of the REPowerEU target of 10 Mt, or 330 TWh, would require approximately five large-scale pipeline corridors.** Based on an initial analysis of supply potentials, demand centres, and TSOs assessments of the ability to repurpose existing natural gas and build new hydrogen pipelines,[12] up to five supply corridors could emerge by 2030. These cross-border corridors, shown in the accelerated EHB network map in Figure 2, can integrate large volumes of renewable and low-carbon hydrogen using solar resources in southern and eastern European countries, and wind resources around the North, Baltic, and Mediterranean Seas. In regions where solar PV and wind resource potential are both abundant, hybrid PV and wind configurations are also an option to provide cost-competitive hydrogen production by drawing on strong renewable potential. The 2030 hydrogen infrastructure map, as presented in figure 2, would consist of a total length of ~28,000 km[13].

Connecting these abundant supply regions to hydrogen consumers in the centre of Europe through cross-border pipeline corridors will become increasingly important as adoption of hydrogen in the transport, industry, and power sectors accelerates and leads to demand outgrowing supply in regions with modest renewable energy production potential. The developments also pave the way for hydrogen pipeline imports from North Africa through Spain or Italy, from Ukraine through Poland, Slovakia or Hungary, or ship imports of hydrogen derivatives via planned new or repurposed import terminals.

10 20.6 Mt of hydrogen corresponds with 680 TWh (lower heating value).

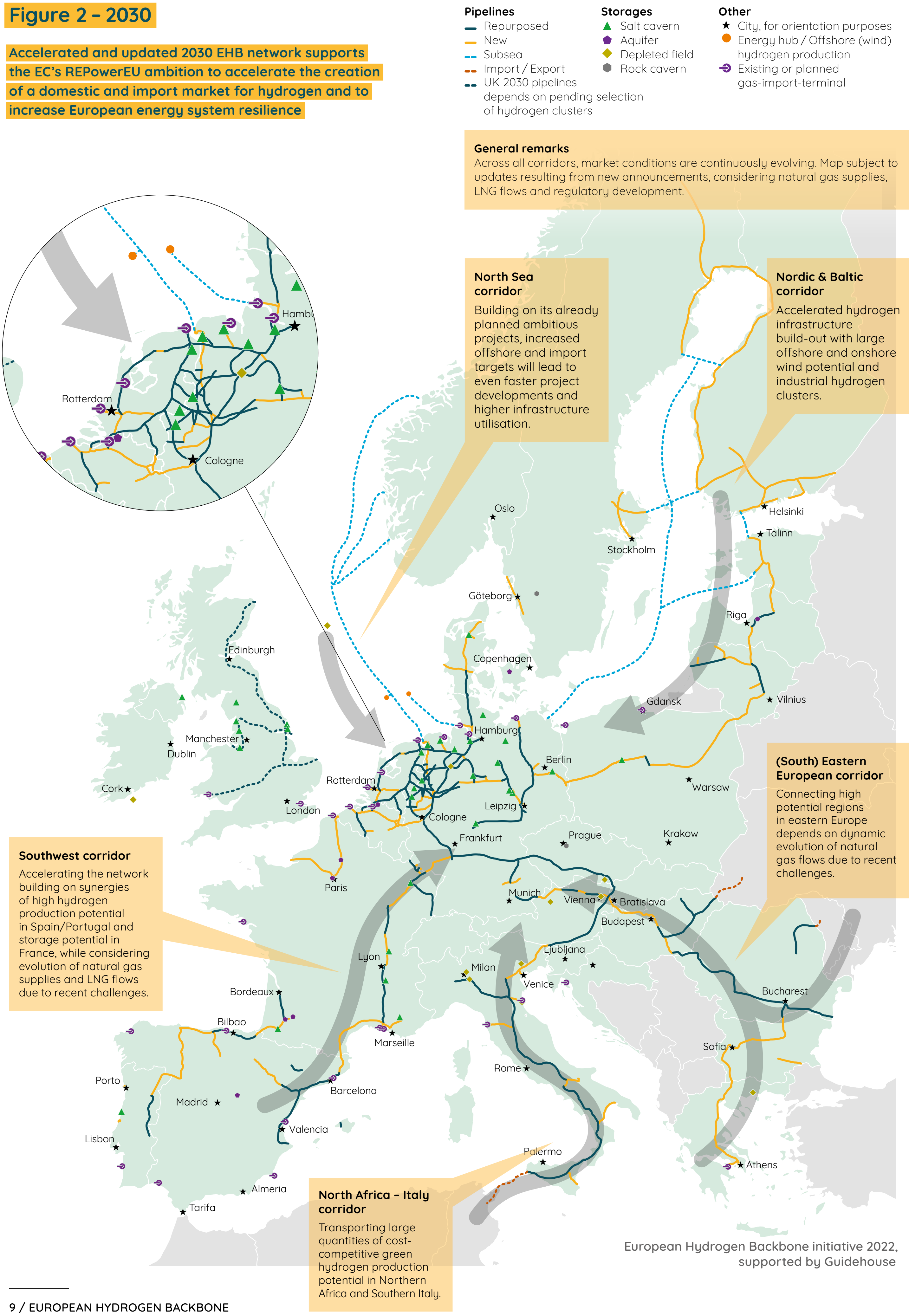
11 13 GW 5000 full load hours is consistent with assumptions used in previous EHB work, however these can vary depending on operational parameters such as operating pressure, steel grade, etc. Detailed techno-economic assumptions used in prior EHB work are documented in the Appendix of this report.

12 EHB (2021) – Analysing future demand, supply, and transport of hydrogen. Source: https://gasforclimate2050.eu/wp-content/uploads/2021/06/EHB_Analysing-the-future-demand-supply-and-transport-of-hydrogen_June-2021_v3.pdf.

13 The kilometres represent all stretches that are visualised in the map, except the dotted import lines from third countries

Figure 2 – 2030

Accelerated and updated 2030 EHB network supports the EC's REPowerEU ambition to accelerate the creation of a domestic and import market for hydrogen and to increase European energy system resilience



As shown in Figure 2, up to five pan-European supply and import corridors can be envisioned to support the European Commission's REPowerEU ambitions. The increased ambition for diversification towards offshore renewables away from fossil fuels, will lead to more renewable hydrogen being transported through each of these five corridors. Owing to rapid developments regarding import projects, more hydrogen imports can be accommodated leading to higher infrastructure utilisation.

In southern Europe, a corridor is likely to emerge connecting supply from Tunisia and Algeria through Italy to central Europe. Drawing also on an extensive and in some areas parallel natural gas network, this corridor will likely be able to leverage repurposed existing natural gas pipelines in Italy, Austria, Slovakia, and Czech Republic to import and transport green hydrogen from North Africa to central Europe. This corridor could provide cost-competitive Tunisian and Algerian and Italy solar and wind based green hydrogen to decarbonise existing industries along the transit route as well as the Southern German clusters in Bavaria, the Rhin-Main area, and Rhinland.

Another corridor could develop to export and transport green hydrogen produced in the Iberian Peninsula. New interconnections between Portugal and Spain, and the Iberian Peninsula and France through the East Pyrenees, could allow all three countries to benefit from the complementary nature of low-cost, high-volume Spanish and Portuguese hydrogen production and underground storage sites, in France and in the Iberian Peninsula, to help provide stable supply for off-takers in the region.[14] This corridor, which would stretch all the way to Germany, can play an important role in decarbonising regional industrial and transport ecosystems in Portugal, Spain and France,[15] and deliver hydrogen at low cost to demand centres in Germany. In the longer term this corridor can also provide access to hydrogen imports from Morocco.

An interconnected corridor is likely to emerge around the North Sea, building on ongoing and planned offshore wind, large-scale integrated hydrogen projects, and ship imports of hydrogen derivatives such as ammonia, methanol, and liquid hydrogen to meet demand around the industrial clusters and Ports of Rotterdam, Zeebrugge, Antwerp, Wilhelmshaven, Brunsbüttel and le Havre.[16]

In the Netherlands, the national backbone can be ready by 2027, connecting all industrial clusters, storage facilities and neighbouring network operators (Germany and Belgium), and by 2030 will function as a ring network. In Germany, hydrogen clusters in the North-West, in the Ruhr area and in the East, the Central German Chemical Triangle, are expected to develop and will be interconnected and linked to hydrogen networks in other North-West European countries.[17]

Significant green hydrogen supply potential based on onshore and offshore wind drive the development of **additional supply corridors that can connect Nordic and Baltic hydrogen supply to the rest of Europe,** building on regional networks around industrial clusters in the regions of Jutland, Göteborg, the Bothnian Bay and industrial clusters in Baltic states and Poland. This supply route can serve numerous new green steel, e-fuel projects in the Nordics, and decarbonise existing industry along the onshore route through Finland, the Baltic states and Poland. Great offshore wind potential can also drive the development of new offshore pipeline connecting Nordic supply with Central European demand. As this corridor will consist mostly of newly built pipelines, development of this route by 2030 is especially dependent on the funding, speed and efficiency of the permitting and planning processes as well as the local market needs.

14 This corridor will for example be able to connect the salt caverns around Lyon and Marseille with the hydrogen stretches around the east coast of Spain. For example, Lacq Hydrogen Project which exploits the synergies of production of renewable hydrogen in Spain and storage in Terega's UGS in France.

15 7 hydrogen clusters were identified in France resulting from a Public Consultation by gas TSOs Terega and GRTgaz. National and European H_2 network interconnections will make it possible to cover possible local production deficits in certain regions. https://www.terega.fr/acteur-de-lhydrogene/consultation-des-acteurs-du-marche-de-l-hydrogene-bas-carbone-et-renouvelable

16 Planned projects include for example Aquaventus, the North Sea Wind Power Hub, the Norwegian energy hub or Danish offshore energy islands, other terminal locations are under investigation such as Stade and Rostock.

17 Based on announced and planned projects, such as the H2ercules project, some updates to the network in 2030 in this corridor are expected.

In East and South-East Europe, a fifth and final corridor could connect hydrogen off-takers in Central Europe to regions with abundant renewable energy in countries such as Romania, Greece, and Ukraine. The vast land availability and high capacity factors for solar and wind, the availability of low-carbon hydrogen from nuclear energy, and the option to repurpose large transit gas pipelines make this region an attractive candidate for large-scale hydrogen production. Nevertheless, the uncertainty concerning the evolution of future natural gas flows in this area impacts the development of this corridor.

By 2030, hydrogen is likely to be imported through both pipelines and import terminals. The split between pipeline and ship imports will depend on import terminal strategies unfolding as well as the pace of hydrogen production scale-up in pipeline export regions such as Algeria and Tunisia. Where the more economically favourable pipeline imports are not available, hydrogen derivatives could be imported via ship to be directly used as methanol or ammonia or to be reconverted to hydrogen for pipeline transmission in the onshore network. Different regions will opt for different approaches and solutions when it comes to hydrogen import and export, based on their geopolitical situation. The updated and accelerated 2030 EHB vision shows that European TSOs are ready to deliver on the infrastructure that is necessary to meet the REPowerEU targets.

2.2. Mature infrastructure stretching towards all directions by 2040

Between 2030 and 2040, the European Hydrogen Backbone will continue to grow, covering more regions and developing new interconnections across Member States. Driven by the ambitious policy environment set in the Green Deal, Fit for 55, and REPowerEU proposals, an increased urgency to meet climate targets, and a rapidly increasing number of projects and initiatives supported by public authorities and industry, the supply corridors will naturally extend into areas where cost-effective pipeline transport of hydrogen is needed to meet market demands.

As large supply corridors come together, a core European Hydrogen Backbone can be envisaged by 2040. This means that a pan-European hydrogen infrastructure can be created connecting 28 European countries, as shown in Figure 3. By 2040, the proposed backbone can have a total length of almost 53,000 kilometres[18], consisting of approximately 60% repurposed existing infrastructure and 40% of new hydrogen pipelines. Assuming that the backbone is equipped with a fit for purpose and technically robust compression system, the proposed network could be able to adequately meet the foreseen 1,640 TWh of annual hydrogen demand in Europe by 2040.[19]

Whereas initially the hydrogen backbone mainly serves industrial hydrogen demand, between 2030 and 2040 hydrogen will increasingly become a significant energy carrier in other sectors, including heavy transport, e-fuel production, the building sector, and long-duration energy storage and dispatchable power generation, thereby complementing the electricity grid to integrate large volumes of renewables in the energy system. Hydrogen imports via connections from export regions such as Namibia, Chile, Australia and the Middle East, and hydrogen import terminals are expected to replace existing natural gas imports and will make up a material portion of future hydrogen volumes.

18 The kilometres represent all stretches that are visualised in the map with the billion euros in the main text, except the dotted import lines from third countries

19 EHB initiative (2021) – Analysing the future demand, supply, and transport of hydrogen. Source: https://gasforclimate2050.eu/wp-content/uploads/2021/06/EHB_Analysing-the-future-demand-supply-and-transport-of-hydrogen_June-2021_v3.pdf.

By connecting hydrogen producers with off-takers, this physical **European hydrogen network could enable the creation of a liquid pan-European hydrogen market,** thereby accelerating deployment of renewables, fostering market competition, and revitalising Europe's decarbonised industrial sector. By 2040, many European countries will be closing in on their respective climate targets. Complementing rapid deployment of renewables and electrification with storable, climate-neutral energy carriers such as hydrogen will be key to ensure the overall affordability and system adequacy of a future climate-neutral energy system. By connecting hydrogen producers and consumers to large-scale underground hydrogen storage sites[20], the proposed backbone could help to integrate renewable energy during periods of oversupply and offer much-needed 'green' security of supply and European energy sovereignty during periods of reduced renewable energy production.

The direct link between hydrogen flows and corresponding network capacities is beyond the scope of this paper. However, an initial study, commissioned by the EC to serve as technical support to the development of the hydrogen and decarbonised gas package proposal published in December 2021, makes use of future EHB transmission and interconnection capacities to estimate the benefits and costs of a pan-European hydrogen network[21]. The participating organisations of the EHB initiative are currently also working on integrated modelling studies, at both Member State and at European level.

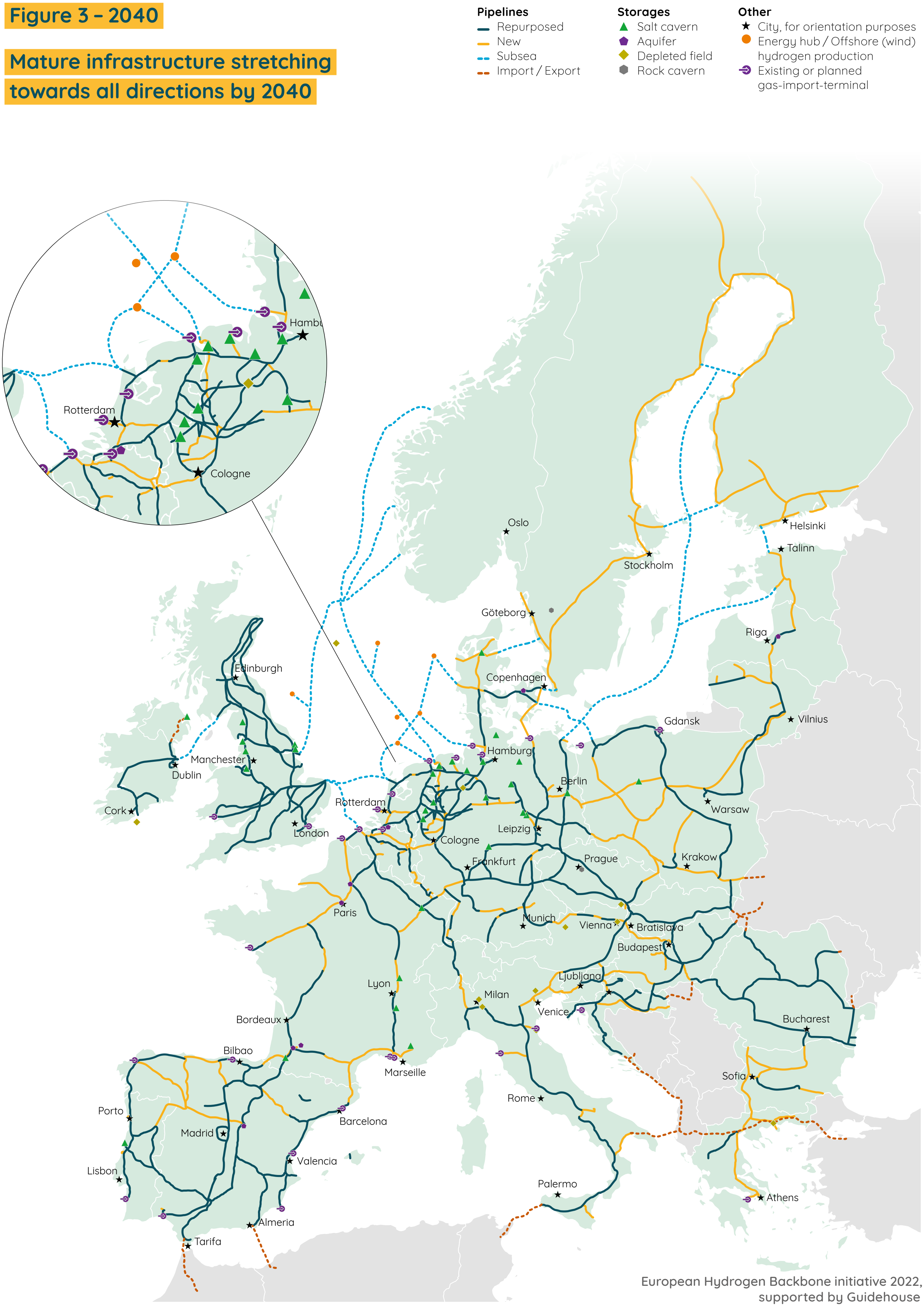
Finally, it is important to note that while most accelerated climate scenarios expect hydrogen demand growth between 2030-2040 to be significant, even more growth in volume is expected to occur during the 2040s. As such, the 2040 backbone displayed in Figure 3 should be considered as a critical milestone, but not a final product. The **backbone as proposed for 2040** represents a foundational network, **"a mature hydrogen highway"**, upon which further developments can be built. Depending on the evolution of the hydrogen market, including the pace and location of development, additional reinforcements and extensions to the backbone can be made to accommodate these ambitions.

20 As a first-order result, GIE (2021) estimates that repurposing all existing European natural gas sites to hydrogen would lead to up to working gas capacity of 265 TWh hydrogen storage, of which 50 TWh in salt caverns and 215 TWh in gas fields and aquifers. The role of underground hydrogen storage is expected to vary from country to country and is subject to national energy market dynamics. Source: https://www.gie.eu/gie-presents-new-study-picturing-the-value-of-underground-gas-storage-to-the-european-hydrogen-system/.

21 METIS study on costs and benefits of a pan-European hydrogen infrastructure (2021). Source: https://op.europa.eu/en/publication-detail/-/publication/c50a12fc-5eeb-11ec-9c6c-01aa75ed71a1/language-en.

Figure 3 – 2040

Mature infrastructure stretching towards all directions by 2040



European Hydrogen Backbone initiative 2022, supported by Guidehouse

3. Accelerating implementation of the EHB

To achieve the EC's ambitious Fit for 55 and REPowerEU goals, and to foster an accelerated development of the European Hydrogen Backbone as shown, this paper presents the following levers to facilitate implementation of infrastructure projects.

The EHB recommends introducing in the REPowerEU plan the establishment of import corridors, including all infrastructure requirements, as a political objective.

Establish a more integrated energy system planning of hydrogen, natural gas, and electricity infrastructure at Member State level. Lead times for large-scale transmission, storage, and port infrastructure implementation – including development, engineering studies, and construction – can take up to 10 years. Integrated infrastructure planning must start today in order to send the right market signals, seize the upcoming investment windows, and have concrete infrastructure projects in place by 2030 and 2035.

Promote efficient measures to facilitate the swift development of a dedicated hydrogen infrastructure by fostering repurposing of existing natural gas infrastructure Regulatory provisions should incentivise rapid roll-out of hydrogen infrastructure – pipeline, storage, and port – including investment in assets that can be repurposed before 2030.

Simplify and shorten planning and permitting procedures for renewable energy and hydrogen projects. Red tape is a major hurdle to the deployment of renewables and hydrogen projects across Europe. Governments and the EU can support project deployment by introducing frameworks for rapid mapping, assessment, and allocation of suitable land for infrastructure projects; and by defining maximum processing times for environmental, permitting, and planning applications.

Unlock financing to fast-track hydrogen infrastructure deployment. Flexible economic models to incentivise investment in hydrogen infrastructure during the volatile market ramp-up years should be explored. On a national level, countries can subsidise upfront capital investments to mitigate utilisation risk during the early years when volumes are scaling up. The EU can also incentivise private project financing and make funding mechanisms such as the Connecting Europe Facility (CEF), Important Projects of Common European Interest (IPCEI) and Horizon Europe funds, available to project developers and promoters.

Encourage international cooperation and create intra and extra-EU energy and hydrogen partnerships. In order to maintain the quality of hydrogen, the EU must create EU-wide accepted standards, regulations and certifications for the production and consumption of hydrogen. It must also enforce these standards on the imports of hydrogen. Member States can explore symbiotic energy and hydrogen partnerships with future exporting countries, either through EU programmes such as Strategic Partnerships for the Implementation of the Paris Agreement (SPIPA), or bilaterally, such as Germany has done with multiple countries from Morocco to the UAE in order to stimulate trade, energy imports, and technology exports.

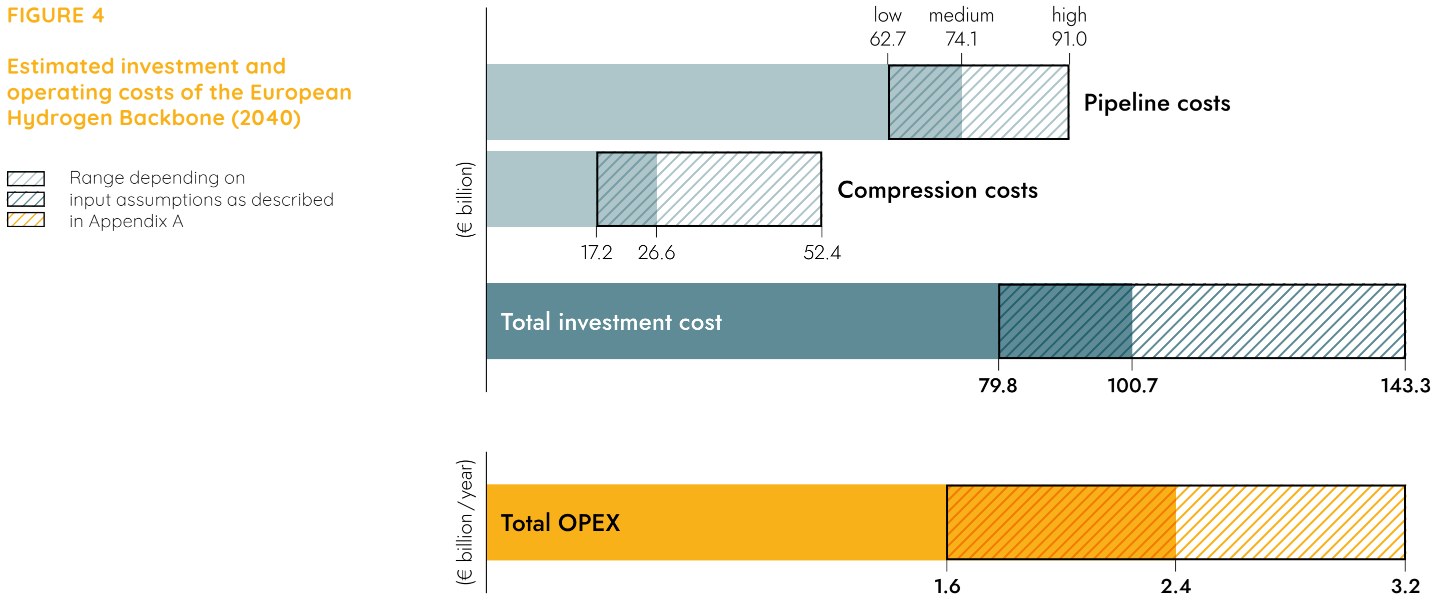
Appendix A. Cost of an expanded European Hydrogen Backbone

Investment and operating costs

Based on the cost figures shown in Table 1, the total investment costs of the envisaged 2040 European Hydrogen Backbone are expected to range from €80 to €143 billion[22] covering the full capital cost of building new hydrogen pipelines and repurposing pipelines for the European hydrogen backbone. Annual operating costs are estimated to be between €1.6 and €3.2 billion when assuming a load factor of 5,000 hours per year[23]. An overview of these costs is given in Figure 4.

FIGURE 4

Estimated investment and operating costs of the European Hydrogen Backbone (2040)



The main reason for the relatively large bandwidth is the uncertainty and variability concerning compression system design and costs. In particular, compression system capital costs depend heavily on the underlying concept design; including whether the project is greenfield or brownfield, the design operating pressure range, n+1 rule implementation,[24] and compressor technology choice (centrifugal or reciprocating).

22 The euro amounts represent all stretches that are visualised in the map, except the dotted import lines from third countries

23 This study considers the backbone from an infrastructure investment perspective and does not take a strong stance on the exact level of network utilisation. A load factor of 5000 hours per year is deemed reasonable, cognizant of the fact this value will change depending on future market developments – and impact resulting costs accordingly.

24 For pipeline transport, the n+1 redundancy rule applies to ensure system availability in the event of component failure.

Levelised transport cost

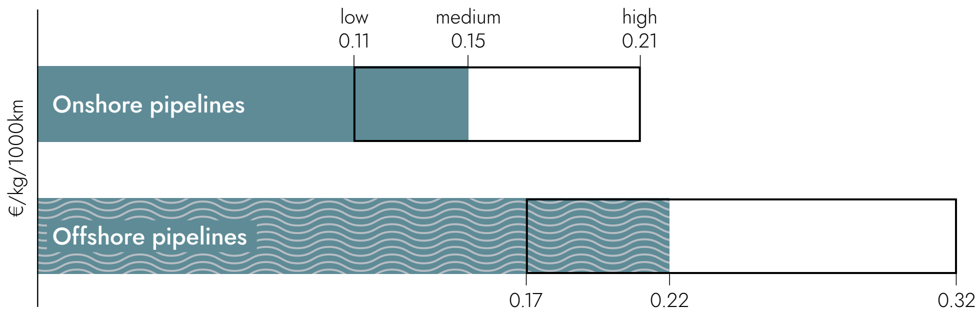
Transporting hydrogen over 1,000 km along an average stretch of the onshore hydrogen backbone, as presented in this report, would cost €0.11 – €0.21 per kg of hydrogen transported (€3.3 - €6.3 per MWh), with €0.15 per kg (€4.5 per MWh) for the scenario with medium cost estimates. This cost estimate would be €0.17 - €0.32 per kg of hydrogen (€4.5 - €8.7 per MWh) per 1,000 km in case the hydrogen is transported entirely via dedicated subsea offshore pipelines. These figures confirm that the EHB is an attractive and cost-effective option for long-distance transport of hydrogen, considering an estimated future production cost of €1.0-€2.0 per kg of hydrogen (€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 – and also reflect their respective distance and capacity-weighted shares within the context of the overall European Hydrogen Backbone[25].

This means that even though smaller pipelines have a higher cost of transport per unit distance, their modest share in terms of length and capacity leads to a marginal impact on overall transport costs when considering the pan-European picture. The cost ranges reflect uncertainties in the estimate of the cost of the European Hydrogen Backbone as a whole. Depending on circumstances, the costs for individual stretches can be lower or higher than the range indicated.

FIGURE 5

Comparison of levelised transport costs for onshore and offshore pipelines for an average stretch of the backbone in €/kg/1000km



Unit cost assumptions

Representative unit capital cost figures for small, medium, large and offshore hydrogen pipelines are summarised in Table 1. These figures use 20-inch (~500 mm), 36-inch (~900 mm), and 48-inch (~1200 mm) as models to represent small, medium, and large pipelines respectively. The offshore pipelines are assumed to have the same dimensions as onshore pipelines and costs are estimated by applying a 1.7x multiplication factor to onshore pipelines of the same diameter.[26] Only using three different pipeline sizes is a simplification of reality, given that the actual backbone is made up of a continuous range of pipeline sizes. Additional underlying cost assumptions such as compressor costs, depreciation periods, and operating and maintenance costs are also shown in Table 1 and are consistent with those used in previous EHB reports.

25 The levelised cost of hydrogen transport per kg per 1,000 km is calculated by multiplying the estimated levelised costs for each pipeline diameter by their respective capacity-distance-weighted shares, i.e., the relative amount of hydrogen transported by that pipeline size across the entire backbone.

26 Offshore pipeline CAPEX and compressor needs (expressed in MWe/km) are estimated in a simplified manner by applying a 1.7x multiplication factor to onshore pipelines of the same diameter. This figure is based on typical offshore-onshore cost ratios seen in existing offshore natural gas pipelines.

These cost estimates are based on gas TSOs' preliminary R&D efforts regarding hydrogen infrastructure. The ranges are determined through comparison with experience investing in and operating existing natural gas networks and based on initial experience in pilot projects. Although some dedicated hydrogen components have been tested in pilot projects, no large-scale hydrogen infrastructure exists to date to provide real historical benchmark figures. Equal to the previous results in 2020 and 2021, these cost estimates are based on running an average single stretch of hydrogen pipeline. They do not incorporate a scenario-based simulation of a full-scale network as is commonly done for network development planning.

TABLE 1

Cost input ranges used for estimating total investment, operating, and maintenance costs for hydrogen infrastructure

Cost parameter		Low	Medium	High	Unit
Pipeline Capex, new	Small	1.4	1.5	1.8	M€/km
	Medium	2.0	2.2	2.7	
	Large	2.5	2.8	3.4	
	Offshore Medium	3.4	3.7	4.6	
	Offshore Large	4.3	4.8	5.8	
Pipeline Capex, repurposed[27]	Small	0.2	0.3	0.5	
	Medium	0.2	0.4	0.5	
	Large	0.3	0.5	0.6	
	Offshore Medium	0.3	0.4	0.5	
	Offshore Large	0.4	0.5	0.6	
Compressor station Capex		2.2	3.4	6.7	M€/MW_e
Electricity price		40	60	80	€/MWh
Pipeline operating & maintenance costs		0.8	0.9	1.0	€/year as % of Capex
Compressor operating & maintenance costs		1.7	1.7	1.7	
Weighted average cost of capital		5.0			%
Depreciation period pipelines		40			Years
Depreciation period compressors		25			

27 Offshore pipeline CAPEX for repurposed pipelines is assumed to be 10% of the CAPEX of the new pipelines. This is a based on Guidehouse desk research and is percentage wise a bit less than for onshore pipelines.

The updated cost estimates are the result of a series of hydraulic simulations conducted by gas TSOs. The modelled scenarios cover a range of point-to-point pipeline transport cases with varying input parameters – selected by TSOs – including pipeline diameter and design capacity. Note that these analyses, while thoroughly conducted, are not exhaustive and merely serve as high-level approximations of what would happen in a real network. Hence, given the simplifying assumptions made in the analyses, these results should not be considered as representative of a fully optimised, actual meshed pipeline grid. Below, Key results are summarised in Table 2 below.

TABLE 2

Overview of unit capital costs and estimated costs of pipeline transport for different pipeline types in the medium scenario

Pipeline specifications		GW[28]	Pipeline Capex	Compression Capex	LCOH	Unit
Small	New	1.2	1.5	0.09	0.16	€/kg/200 km
	Repurposed	1.2	0.3	0.09	0.05	
Medium	New	4.7	2.2	0.32	0.35	€/kg/1000 km
	Repurposed	3.6	0.4	0.14	0.12	
Large	New	13	2.8	0.62	0.19	
	Repurposed	13	0.5	0.62	0.09	
Offshore Medium	New	4.7	3.7	0.54	0.60	
	Repurposed	3.6	0.4	0.23	0.15	
Offshore Large	New	13	4.8	1.06	0.32	
	Repurposed	13	0.5	1.06	0.14	

28 The pipeline capacities are kept constant in comparison with the previous EHB report from April 2021 and are based on 75% capacity. Furthermore, the operating pressure for large pipelines was assumed to be 80 bar, and 50 bar for medium and small pipelines.

Appendix B.
Country-specific developments

The evolution of a hydrogen network in the maps mentioned earlier in this report presents a vision. Further detailed modelling and a flow study are needed to define the shape, size and ordering of hydrogen infrastructure, alongside policy support, development of hydrogen markets and hydrogen supply scaling up. The evolution of a hydrogen network in these maps illustrates one of many scenarios for the development of a dedicated hydrogen infrastructure. The EHB initiative considers blending and deblending hydrogen in/from natural gas transport infrastructure as a suitable step especially during the 2020s and early 2030s in the transition towards a dedicated hydrogen pipeline transport network.

Table 4 below sketches the general background and provides additional information on hydrogen infrastructure development for all participating countries. This information is provided by the respective energy infrastructure company (or companies) of each country.

TABLE 4

Country-specific narratives

Country / Background	Hydrogen infrastructure development
Austria  Austria's current transmission gas network is operated by two TSOs, TAG and GCA and stretches over ~1,700 km. TAG mainly transits natural gas from the eastern border with Slovakia towards Italy. GCA's network serves a dual function and simultaneously transits gas mainly from Slovakia towards Germany, Hungary and Slovenia and provides gas via its primary distribution system for domestic customers in Austria. In the future, both TSOs expect to transport hydrogen, either blended with methane or in pure form. The latter can be carried out via dedicated hydrogen pipelines or via deblending facilities, which extracts hydrogen from the methane/hydrogen mixture. Austria has an ambitious target to produce 100% of its electricity from renewable sources by 2030 and a carbon neutrality target by 2040, although this is enabled partly by its hydro sources, solar PV and wind will need to scale up substantially. Future hydrogen use will increase in Austria with its industry presence in fuels, chemical and steel. However, the main driver for the emerging hydrogen infrastructure would be the transit role, for the east-west corridor (Ukraine – Slovakia – Austria – Germany) and for the north-south corridors (North Africa – Italy – Austria –Germany). Next to the transit role, the network would also serve residential and industrial customers.	Until 2030, a first step towards a dedicated hydrogen network could be taken via blending and deblending into/from the existing infrastructure connecting Slovakia, Hungary, Slovenia, Italy and Germany. By 2030, GCA's WAG pipeline could be entirely looped and one of TAGs parallel pipelines could be repurposed to transit hydrogen in both directions. With this, the Austrian network could serve two corridors to supply Germany with green hydrogen, Ukrainian green hydrogen from Slovakia via Austria and North African green hydrogen from Italy via Austria. Upon completion, Austria's grid would be ready as of 2035 to serve as a complete hydrogen hub in the region. Bidirectional hydrogen transportation possibilities at all interconnection points could be in place. In addition, GCA's network would also transport H_2 to Austrian (industrial) customers, such as one of Europe's largest steel plants in Linz, which is already running trials for hydrogen-based steelmaking and a large refinery located near Vienna.

Country / Background

Hydrogen infrastructure development

Belgium

fluxys

Fluxys Belgium is the owner and operator of gas transmission, storage and LNG regasification facilities in Belgium. The network consists of 4,000 km of pipelines and 18 interconnection points with neighbouring countries and import facilities. Fluxys is ready to build the gas network of the future. They plan to progressively reconfigure their natural gas network in Belgium towards the future energy system. They have taken steps with Belgian industrial players and policymakers to identify the potential for hydrogen production and consumption and the infrastructure needed. The timing of the investments for new pipelines and repurposed pipelines will however depend on the evolution of natural gas demand and the uptake of hydrogen demand. Considering this and in line with the feedback received from the market, the first H_2 infrastructure could be ready by mid-2026.

The Belgian national backbone is expected to emerge through developments mainly in and around the industrial clusters of Antwerp and Ghent, and along the industrial valley in Wallonia. Given the proximity between Antwerp and Rotterdam, port-to-port interconnections with the Netherlands are likely. In addition, interconnections with France and Germany will provide Belgium access for import/export of hydrogen from/to neighbouring countries. Hydrogen demand in Belgium in 2040 is indeed expected to exceed production capacity, so imports and exports with all neighbouring countries including the UK – if technical and economic conditions are right – and imports through the Zeebrugge terminal could be paramount in shaping the North-Western European Hydrogen infrastructure development. As such, thanks to all the interconnections and import facilities, Belgium will have become a true hydrogen hub importing and transiting H_2 to neighbouring countries.

Bulgaria

BULGARTRANSGAZ

Bulgartransgaz EAD is a combined operator performing licensed activities of natural gas transmission and storage. The company operates 3 276 km high pressure gas pipelines and Chiren Underground Gas Storage facility.

Bulgaria has strategic geographic location and well-developed gas infrastructure. By implementation of the already completed and planned new projects, proved itself as an important factor in ensuring energy security and diversification of gas sources and routes for the region.

The company's gas transmission system has interconnections with all neighbouring countries – Greece, North Macedonia, Romania, Serbia and Turkey. Bulgartransgaz EAD is continuously developing its infrastructure both for transmission and storage. The ongoing projects for expansion of Chiren UGS, raising cross-border transmission capacities and developing the national transmission network are of utmost importance for the realisation of the Balkan Gas Hub concept.

Bulgartransgaz EAD welcomes the EU's plans for decarbonisation of the energy and industrial sectors and strives to be adequate to the pan-European priorities in the fields of climate and energy. In line with the European and National goals for climate neutrality and large-scale hydrogen deployment, Bulgartransgaz EAD is currently developing several projects in the field of hydrogen transmission:

- H_2 ready pipeline in Maritsa Coal Region in Bulgaria;
- Retrofitting of the existing gas transmission network for H_2/natural gas blends;
- New dedicated H_2 infrastructure for transmission of pure hydrogen between the region of Sofia and the Bulgarian-Greek border near Kulata (connection with DESFA), allowing future expansion to Romania and the East Maritsa region.

These projects have the potential to become part of future European hydrogen transmission corridors.

Country / Background

Hydrogen infrastructure development

Croatia

Plinacro is the Croatian gas transmission system operator and operates more than 2,500 km of transmission pipelines. The Republic of Croatia has a well-developed gas transmission and distribution system. The length of the distribution system is over 18,000 km, supplying gas directly to more than 680,000 consumers in 19 out of 20 counties and the City of Zagreb (if indirect users supplied over the district heating system are taken into account the number of natural gas users is significantly higher). The gas transmission system is connected to the regional and European gas system via the interconnections with Hungary and Slovenia, while through the LNG terminal and evacuation pipelines it is connected to the global LNG market and it enables gas transmission towards the regional and European market.

Plinacro aims to remain an esteemed and leading infrastructural energy entity in the transmission business in the Republic of Croatia and an important strategic energy partner in the region and the European Union, which enables its users to meet their energy requirements in a transparent and socially and environmentally responsible manner.

Utilization of hydrogen and decarbonization of the Croatian and regional gas market will enable Plinacro and other gas market players to remain important part of the future EU low carbon energy society.

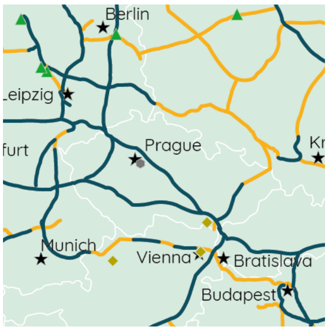
Infrastructure requirements for hydrogen transmission in a short-term period will remain limited. Mixing of hydrogen with natural gas is expected.

In the second phase, infrastructure will transport hydrogen not only for large customer clusters, but also for supplying energy to the residential and commercial buildings.

Development of the future decarbonised infrastructure will be based on the following guidelines:

- All major interconnection and transmission gas pipelines planned in the short time period will be developed as hydrogen-ready,
- Planning and reconstruction of the gas system for receiving and adding decarbonised gases into the natural gas stream will begin. This includes the development of a “smart gas network”.
- In compliance with the plans of the neighbouring operators, the existing interconnections will be repurposed to transport hydrogen by 2040,
- Hydrogen will be supplied to all major urban centres, the entire 75-bar system and parts of 50-bar system will be repurposed to receive and transport 100% H_2, while it is anticipated that local biomethane production will be able to supply other areas,
- After 2040, the existing location of the LNG terminal will be repurposed to receive decarbonised gases and, if necessary, new evacuation infrastructure will be constructed,
- Potential new corridors for the transmission of decarbonised gases from the eastern Europe and the southern and eastern Mediterranean countries towards the central Europe will be developed.

Czech Republic



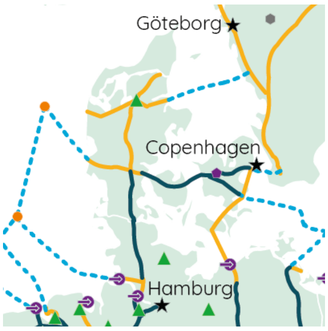
The Czech Republic’s gas TSO, NET4GAS, operates around 4,000 km of pipelines consisting of three major branches of double or even triple pipelines which serve for international transit – connecting Germany, Slovakia and Poland – while also covering domestic demand. NET4GAS sees the gas infrastructure as an enabler of decarbonisation in the energy sector and expects to transport hydrogen (and other renewable or decarbonised gases) in the future. Due to its geographical position, NET4GAS will remain an important transit TSO as it can transport hydrogen from an Eastern direction (e.g., from Ukraine via Slovakia), from a Southern direction (e.g., from North Africa via Italy and Austria) as well as from the North-West (e.g., Germany). In 2021, the Czech Republic published its own hydrogen strategy, which it assumes that the Czech Republic, to meet domestic hydrogen demand, will need to import hydrogen from abroad by repurposed pipelines. Potential utilisation of hydrogen is expected in carbon intensive and hard-to-abate industrial processes such as ammonia, cement, steel production or fuels and transportation. But also, in the power production and (district) heating sectors there is an increased interest in hydrogen as an energy carrier.

There are several long-term gas transmission contracts in place. The major contracts expire at the beginning of 2035 and in 2039, respectively. The possibility for hydrogen transportation from the Eastern border with Slovakia to the Western border with Germany is shown in the updated maps in 2030. This option would – under certain circumstances still to be analysed – allow for initial hydrogen imports from Ukraine and North Africa in the early 2030ies by connecting major non-EU supply sources and regions with the hydrogen demand centres in the EU. In addition, by 2035 the Gazelle pipeline could provide a large-scale connection for hydrogen transportation between the Northern and Southern regions of Germany. The recent analysis has shown higher probability of East-West flows in the medium term horizon. For such a transport, the southern branch of the N4G system is a more suitable option. For 2040, the possibility for hydrogen transportation from the Eastern border with Slovakia to the border with Germany could be further strengthened by a pipeline on the northern branch which could provide an additional entry point to the EU hydrogen markets. Should the priorities on the respective entry into these markets change, such option may become available earlier.

As indicated by the National Hydrogen Strategy, additional hydrogen demand in the industrial regions, for instance close to the Polish border, is becoming more realistic in the late 2030s’. In the updated maps, there is a new connection to the hydrogen backbone based on a combination of partly repurposed and newly built pipelines. Such pipelines might also be providing a connection to the Polish system. Such option still has to be analysed. In addition, NET4GAS currently runs the incremental capacity process for a new connection to Austria. On the Czech side such a connection will be hydrogen ready and, if implemented, might provide additional hydrogen transportation options to the region.

Denmark

ENERGINET



Denmark has set out a 70% greenhouse gas emissions reduction target by 2030, and in December of 2021 the Danish government published its proposal for a Danish Power-to-X (PtX) strategy with an ambitious Danish capacity target of 4-6 GW electrolysis by 2030. Infrastructure is a large part of the proposal, and the government addresses this matter with ambitions to examine the regulatory barriers for the development of a hydrogen market and to support the export of hydrogen and PtX products by creating the framework for a hydrogen infrastructure that can eventually be linked to a common European hydrogen infrastructure. The strategy also mentions innovative activities such as offshore PtX production in relations to the development of the two Danish energy islands, which in the first phase will supply 5 GW of electricity from offshore wind, rising to at least 12 GW once fully developed.

Denmark's electricity and gas TSO, Energinet, owns and operates a gas transmission pipeline grid of around 925 km, with cross border connections to Germany and Sweden. An expansion with the Baltic Pipe connecting Norway, Denmark with Poland will be in operation from 2022, expanding the pipeline grid to approximately 1,250 km. Energinet owns and operates two gas storages facilities, one cavern and one aquifer storage. A market dialogue with 19 actors was carried out in 2021 by Energinet and the Danish Energy Agency, indicating the need for access to a hydrogen infrastructure already before 2030 to support the several large-scale electrolysis projects that have been announced in Denmark, totalling around 6.5 GW of installed capacity by 2030. Energinet has initiated the process of evaluating a 93 km stretch of infrastructure considered eligible for repurposing to hydrogen transport, subject to successful completion of the prepared requalification and material testing program.

By 2030, initial development of the Danish backbone consists of newly constructed hydrogen pipelines and the repurposing of an existing natural gas pipeline, connecting large scale hydrogen producers and industrial clusters with large scale storage facilities and export opportunities though the interconnection with Germany. By 2035, Denmark seeks to draw upon its significant offshore wind resource in combination with electrolysis to attract new industries, such as e-fuels. The energy islands together with the buildout of large-scale onshore PV will be the drivers for the expansion of the national hydrogen infrastructure, which in the west expands into the North Sea enabling offshore hydrogen production at the energy island. The eastern route is meanwhile extended by connecting the Copenhagen area with Sweden and through a new transmission pipeline that could be constructed from the Copenhagen area southwards towards Germany. By 2040, the east and west backbones are connected across Denmark by repurposing the Baltic Pipe, which is further extended towards Poland to enable a supply connection, while a northern connection from Jutland towards demand areas in Sweden also emerges. In the North Sea a hydrogen interconnector is established between the Danish Energy Island and the Dutch offshore hydrogen production in area 6, thus enabling export of hydrogen produced offshore. The 2030 – 2040 maps show many possible developments for hydrogen transport, which will co-exist with the biomethane grid. What specific pipeline developments are realised depends on the societal economic value, and demand situation in the future.

Estonia

elering

Estonia's electricity and gas TSO, Elering, operates a pipeline grid of 977 km, including the subsea interconnector with Gasgrid Finland. With offshore wind potential of 7GW and 24TWh[16], Estonian offshore wind energy potential alone will far exceed its domestic electricity demand (link). Without the introduction of green hydrogen, the offshore wind production and installed capacity may not even reach its full potential due to large amounts of energy which could be curtailed during high wind periods. Connecting the national backbone to the European Hydrogen Backbone supports system integration of large volumes of offshore wind, enabling a relatively small country to supply multiple potential demand regions across Europe. The benefits of realising the Baltic Sea offshore- and Nordic onshore wind potential would not only be regional. Connecting the Baltic region with Central Europe with an onshore or offshore pipeline would enable Europe to increase its energy self-sufficiency and energy security. Green hydrogen would allow for integration and storage of the offshore wind and transport this green energy to hard-to-decarbonise regions in Central (Eastern) Europe. Hydrogen pipeline network could enable the use of hydrogen in dispatchable power plants, thus guaranteeing the security of supply for electricity.

In the beginning of the 2030s, the first offshore windfarms are expected to be present west of Estonia, in the Baltic Sea. Due to the large volumes of energy produced in offshore wind farms, compared to the relatively small electricity demand in the Baltics, hydrogen production could be economically feasible early on. This renewable energy oversupply could open a possibility to export green hydrogen to Central Europe with pipelines inthe second half of 2030s. Until the Estonian renewable energy production capacity ramps up, Estonia could act as an onshore transit corridor from Finland to other Baltic states and Poland. As such new build hydrogen pipelines would be a great undertaking for a small country like Estonia, the realization would largely depend on the demand side interest funding and multinational agreements. For this hydrogen transit pipeline to be possible in 2030, strong incentives from both EU, regional and national level are needed, in the form of rapid planning, permitting, securing appropriate funding and agreement on tariffing.

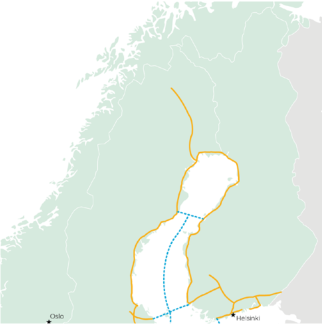
By 2040 further offshore wind power expansion is expected together with hydrogen production in western Estonia, that could supply other regions needing green hydrogen.

Country / Background

Hydrogen infrastructure development

Finland

GASGRID



Finland's gas transmission system operator (TSO) Gasgrid Finland owns and operates a network in the south of Finland of 1,300km and a subsea interconnector into Estonia with Estonian gas and electricity TSO Elering.

Finland has an ambitious carbon neutrality target already for 2035. The demand for clean hydrogen in Finland could grow and scale rapidly in industry, considering the 2035 carbon neutrality target and strong presence of steel, chemicals, and fuel production. Thus, hydrogen and power-to-X production has significant potential in Finland.

Finland has also significant onshore and offshore wind potential. Fingrid Oyj (electricity TSO in Finland) has received already 157 GWs of inquiries for wind power connections. In one of its scenarios Fingrid is estimating 25 GW of wind power already by 2035[19]. Wind power is estimated to develop at a very cost-competitive price level in Finland providing significant opportunities for hydrogen production. In addition, district heating is common in Finland, which increases the competitiveness of hydrogen projects as there is the possibility to utilise heat from electrolysis process for production of district heating. Furthermore, land and water availability are additional factors supporting competitiveness of hydrogen production in Finland adding to the large potential of hydrogen production in Finland.

The need for energy system integration is a key driver of development of a hydrogen network which could support the development of a carbon neutral energy system in Finland by providing intermediate energy storage and efficient transport of renewable energy from supply sources to the demand locations. It would also enable creation of a hydrogen market connecting hydrogen producers and consumers. Later-on the national hydrogen network could also be connected to hydrogen networks in other countries, connecting Finland with larger European hydrogen markets with expected significant increase in hydrogen demand. This would enable hydrogen export and also access to central European gas storage facilities.

Hydrogen infrastructure in Finland is envisioned to develop in three strategic geographical areas; Bothnian Bay region and the west-coast with significant renewable energy sources and identified H_2 demand, south and south-east Finland (Uusimaa & Kymenlaakso areas) with significant existing and expected hydrogen demand and the Southwest Finland & Satakunta areas with potential hydrogen demand and significant renewable energy resources.

The development of these hydrogen valleys could emerge due to identified significant use of hydrogen in industry (low-carbon fuel production, chemicals, steel, mining) and possibility to utilise clean energy resources for hydrogen production as well as for supporting also Finland in achieving its 2035 carbon neutrality targets.

As a large part of the supply and demand is expected to develop in regions where there is no (or only limited) existing gas transmission infrastructure, the hydrogen infrastructure is envisioned to be based on new built pipelines.

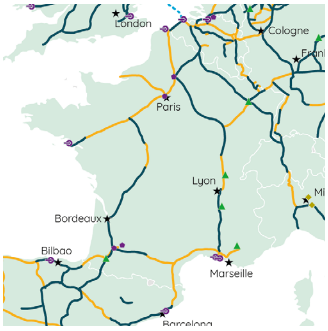
Therefore, Gasgrid Finland and Nordion Energi (Swedish gas TSO) have started to jointly develop a large scale greenfield cross-border hydrogen infrastructure – Nordic Hydrogen Route https://nordichydrogenroute.com/ - in the region of Bothnian Bay with the target of having the network operational by 2030. The Bothniab Bay onshore interconnection to Sweden could create a Finnish-Swedish hydrogen market at the Bothnia Bay area. Also, another interconnector to Sweden could be developed with direct subsea route crossing the Gulf of Bothnia with potential offshore connection also to Germany.

In addition, the Finnish hydrogen network could develop around hydrogen valleys in the south, southeast and southwest of Finland already during this decade. To support the development of the energy system and creation of hydrogen market, the hydrogen valleys could also be connected. A connection along the west coast of Finland enables more extensive utilization of wind for hydrogen production and aids the energy transfer from north to south. A possible subsea interconnector to Estonia connects Finland to the Baltics and to potential demand markets in central, northern and eastern Europe.

By 2040, national hydrogen valleys are envisioned to be connected, and a national hydrogen network developed. Up north, the hydrogen grid could extend further north, and potentially also additional north-south pipelines could be developed. Even further expansion of the Finnish hydrogen network could facilitate accelerated deployment of wind power to fully utilise the potential enabled by great land availability in the northern and eastern parts of Finland.

Country / Background

France



France's current gas network is operated by GRTgaz which operates 32,000 kilometres of pipelines and Teréga, which operates a 5,000 km network in the South-West. The networks serve industry, power and residential customers while GRTgaz also transits gas to Switzerland, Italy, and Teréga transports gas to and from Spain, connecting the Iberian peninsula. Both TSOs are convinced that hydrogen and biomethane, next to electrification, will play an pivotal role in the future French energy system. GRTgaz has ongoing hydrogen projects such as mosaHYc, Jupiter 1000, Rhyne, Hynframed while Teréga is involved in trials around hydrogen storage as HyGéo project and studying industrial applications in the Lacq region cluster (Lacq Hydrogen project), building on synergies with the cost-competitve renewable hydrogen produced in Spain and locally produced hydrogen. As shown by industrial stakeholders in the study "The role of hydrogen transport and storage infrastructure: An opportunity for industrial competitiveness", infrastructure at the national level can have hydrogen clusters benefit from drastic price reductions (https://systemesenergetiques.org/le-role-des-infrastructures-de-transport-et-de-stockage-dhydrogene-un-enjeu-de-competitivite-industrielle/).

Hydrogen infrastructure development

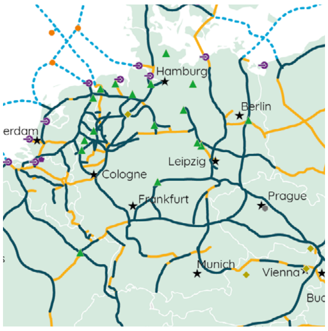
By 2030, regional dedicated hydrogen networks will emerge around industrial clusters, with existing fossil hydrogen production or consumption, in Dunkerque, in the Seine Valley from Le Havre to the vicinity of Paris, and around Lyon, Lacq and Marseille. The hydrogen cluster around Dunkerque will be supplied with decarbonised hydrogen from offshore wind, as well as low-carbon hydrogen. This cluster will also co-benefit from the hydrogen valleys in Belgium and the Netherlands. In the east of France, a regional cluster will also develop at the border between France, Germany, and Luxemburg with the commissioning of the mosaHYc project. Another Hub will also emerge in the south of Alsace were clean hydrogen is needed in the fertilizer and chemical industry, paving the way for an interconnection with Switzerland and Germany in the longer term.

The southern clusters in Marseille-Fos and Lacq are also expected to have access to green hydrogen from solar PV and Mediterranean offshore wind. Lastly, dynamic development of green hydrogen for fuel cell projects and industrial uses is expected to continue and to lead to a need for a dedicated hydrogen pipeline in the region surrounding Lyon. As of 2030, a third interconnection between the Iberian peninsula and France will be operating, concretising the Backbone.

By 2035, additional hubs emerge near Saint Nazaire/Nantes, Bordeaux and along the Mediterranean coast, powered by offshore wind or low-carbon electricity and combined with the evolution of Seaports activities. Those hubs will connect to Region of Paris, and to Lyon along the Rhone Valley, thus enabling the decarbonisation of existing grey hydrogen consumptions and the development of new hydrogen uses in mobility (road, inland navigation, rail, airports). The North-West of France will also be connected to the East of France and to the Region of Paris via the retrofitting of existing gas pipelines. This will enable interregional transit and an easier integration of renewable electricity in the energy system, and it will bring flexibility to the system. The French network will also allow a transnational transit from Spain to Belgium, Germany or Luxembourg. By 2040, a mature network has emerged of mostly repurposed pipelines which has 3 interconnectors with Spain, while also connecting to Belgium, Germany, and Switzerland. The three interconnectors to Spain enable security of supply and flexibility in the large, expected flows of hydrogen from Spain and possibly North Africa into the rest of Europe. On the west side another stretch also provides a different route within France to transport hydrogen, while also serving local customers and industry on the way. In the South, Teréga's storage locations would build on synergies with renewable hydrogen from Spain and Portugal, enabling a stable and secure hydrogen supply further up North.

Country / Background

Germany



OGE, headquartered in Essen, operates the largest German gas transmission system spanning 12,000 kilometres. Two thirds of natural gas consumed in Germany flow through OGE's pipeline system, comprising about 100 compressor units and about 1100 exit points. With its OGE 2030+ strategy implemented in 2018 the company defined a new purpose, namely, to enable energy supply today and in the future energy mix. While dedicated to providing efficient and reliable transport services for natural gas, the main focus in business development today is to become a leading provider of infrastructure in a decarbonised energy system in Germany and Europe, re-purposing natural gas infrastructure for transporting pure hydrogen, securing international import routes for hydrogen and investigating the transport of CO_2 are key areas of activity today.

ONTRAS Gastransport GmbH is a national gas transmission system operator in the European gas transport system based in Leipzig. ONTRAS operates Germany's second-largest gas transmission system, with approximately 7,700 km of pipelines and about 450 interconnection points. ONTRAS links the interests of transport customers, traders, regional network operators and producers of renewable and decarbonised gases. Since 2013, they have been transporting green hydrogen from two power-to-gas plants, as an admixture in their network. In the Bad Lauchstädt Energy Park real laboratory, they will be converting approx. 20 kilometres of natural gas pipeline to pure hydrogen by 2024. And with their IPCEI projects, they are driving forward the development of a hydrogen economy in Eastern Germany.

As result of Germany's federal election in September 2021 the new Federal Government consists of a coalition between the Social Democrats (SPD), the Greens and the Free Democrats (FDP). The new government coalition intends to pursue the goal of climate neutrality by 2045 set by the previous Government. In its coalition treaty the Government proclaims a technology neutral approach to energy policy that includes cross-sector instruments aimed at achieving these targets. In addition, the sector-specific targets of the current Climate Protection Act will be replaced by holistic monitoring of all sectors in a revision in 2022.

Hydrogen features prominently in both, the Government's industrial policy and its energy policy strategy. For 2022, the Government has announced the overhaul of the National Hydrogen Strategy, published by the previous government coalition in 2020. Hydrogen is considered alongside electricity as a prerequisite for Europe's ability to act and compete in the 21st century. The Federal Government expects high future demand for hydrogen. Accordingly, the hydrogen economy is to be ramped up quickly and comprehensively with the necessary resources. The primary focus is set on domestic green hydrogen for which the government has announced to raise the target for installed capacity from 5 to 10 GW by 2030. However, blue hydrogen is also considered an option. Generally, hydrogen imports will play a major role. Appropriate hydrogen networks and import structures are to be created timely also within international co-operations. Moreover, the new Government's plans to accelerate approval procedures. It considers gas-fired power plants as a prerequisite for system stability in the transition to a climate neutral economy and recognises the need for additional capacity if H_2-ready.

In November 2021, the German TSOs published maps for a German H_2 grid in 2030 and 2050. These demonstrate the feasibility to establish a cost-efficient and reliable hydrogen grid in Germany.

Hydrogen infrastructure development

As part of the network development plan (NDP) 2020-2030, the German transmission system operators (TSOs) have published first plans for an initial national hydrogen network 2030 based on a market survey in 2019. Further elaborations by the TSOs regarding projections about future production and demand of hydrogen have resulted in the national hydrogen network maps for 2030 and 2050 published by FNB Gas in November 2021. These maps feature more extended hydrogen networks than those displayed in the network development plan (NDP) 2020-2030, as a higher hydrogen demand and subsequently larger transport volumes are taken into account. The work is based on a scenario for the production and use of hydrogen in Germany developed together with the consulting company 4Management on the basis of the recognised DENA pilot study I (TM95).

The NDP 2022-2032 is currently being prepared and its publication with updated hydrogen networks will take place later this year.

The German hydrogen network 2030 connects different demand clusters like Ruhr Area, Rhine-Main Area, Eastern Germany, Central German chemical triangle and Bavaria with hydrogen sources in Germany, especially in the North, and with important import routes. As such, pipeline connections to the Netherlands, the North Sea and to Denmark and to Poland and the Baltic Sea for integrating offshore pipelines and possible imports are foreseen. While in the Southeast import connections to Austria and the Czech Republic emerge. In the West, connections to Belgium and France occur, while a new connection to Poland in the East will be available for imports to meet growing national demand in different regions.

The compiled German H_2 network has a total length of about 5,200 km by 2030, with some 3,700 km of repurposed natural gas pipelines, and would be able to meet a hydrogen demand of around 70 TWh.

By 2040, a new interconnection emerges to Switzerland and an additional connection with Poland and Czech Republic, thereby further enhancing security of supply.

The German H_2 network for 2040 is derived from the FNB Gas network publications for 2030 and 2050.

(The published FNBGas H_2 network for 2050 has a total length of about 13,300 km with about 11,000 km of repurposed natural gas pipelines and can provide an energy quantity of 504 TWh (net calorific value) at a peak demand of around 110 GWh/h.)

Country / Background

Hydrogen infrastructure development

Great Britain

National Grid owns and operates the National Transmission System in Great Britain, a network consisting of approximately 7,630km of pipelines. The UK government has targeted at least 10GW hydrogen production capacity and 40 GW offshore wind by 2030, with four low carbon industrial clusters established. A dedicated hydrogen transmission system is expected to emerge in Great Britain (the island consisting of England, Scotland and Wales) initially through the phased repurposing of existing natural gas transmission pipelines to join GB's largest industrial clusters (Grangemouth, Teesside, Humberside, Merseyside and South Wales). This will provide resilience to the clusters and could support the conversion of some industries outside of these clusters. The initial development of the emerging hydrogen backbone in GB aims to utilise and repurpose pipelines to transport hydrogen, whilst still maintaining the security of supply on the existing natural gas transmission system. Further conversion of remaining pipelines will likely develop at a later stage and may require small sections of new pipelines to enable the transition.

By 2030, up to four of the five industrial clusters could be connected and will form the basis of a GB hydrogen transmission backbone. Due to the sensitivities around industrial cluster developments, National Grid Gas does not hold any views on the phased sequencing of which industrial clusters are likely to connect first as it relates to this study. Additionally, there may be connections to St Fergus in north Scotland and Bacton on the east coast, providing additional hydrogen supplies which could help integrate the large amounts of renewable energy from offshore wind. By 2035, it is possible that all clusters could be connected. A converted pipeline to Bacton, located on the east coast, could enable future hydrogen flows across the interconnectors between GB and Belgium and GB and the Netherlands once ready. Further repurposed pipelines may start to emerge between 2035 and 2040, including a connection to Moffat, enabling hydrogen to flow across the interconnector between GB and Ireland alongside natural gas flows. As hydrogen production scales, further expansion of this hydrogen network will occur throughout the 2040s enabling a greater reach across industrial, power, transport and domestic heating sectors. The maps represent the selection of pipelines that could have started the hydrogen repurposing process but may not have completed full conversion by the date on the map. Sequencing and formally defined routes have not been determined, therefore some of these pipelines could be converted in the following 5 to 10-year period.

Greece

Greece's TSO is DESFA, which operates a relatively new network of 1,456km. Greece's excellent conditions for both wind and solar power would allow the complete phase out of coal-based power plants by 2028 or even earlier. There are plans to increase installed capacity of Wind Power to 7 GW and Solar PV to almost 8 GW, as stated in its NECP. There is a current hydrogen production capacity (captive) in Greece is 150 thousand ton/y, from fossil fuels, covering a demand of 5 TWh (mostly from refineries and ammonia production industries).

The three main industrial clusters, in Athens, Corinth and Thessaloniki, are potential large demand sources for hydrogen. In addition, according to the recently developed Master Plan for the decarbonisation of the lignite production area of Western Macedonia, there is the large potential of hydrogen production in the region This potential stems from the expected deployment of large scale PV plants, along with the potential for the use of hydrogen locally or its transportation through the new hydrogen-ready pipeline DESFA is deploying in the region. At the same time, several energy players in the country are planning their actions towards the production of green hydrogen, enhancing the efforts towards the "greening" of the Greek energy sector. The cluster project "White Dragon", along with similar projects that propose hydrogen production, stands today as the first step to make hydrogen volumes a reality in the country.

It is obvious that a Hydrogen Backbone will be needed to reconcile substantial differences in hydrogen supply potential and hydrogen demand across the country. The backbone will also serve to connect the national hydrogen system to neighbouring regions, thus providing security of supply and market integration.

By 2035, Greece's main industrial clusters in Athens, Corinth and Thessaloniki would be connected, with new dedicated hydrogen pipelines following the existing natural gas route. The potential hydrogen cluster in West Macedonia will also be connected to Thessaloniki, near the existing connection to TAP, through the new, hydrogen-ready pipeline in the region, which is currently under development. Storage could be available in the form of an aquifer near the Island of Thasos. This dedicated hydrogen pipeline will offer the opportunity to potential large hydrogen consumers across the country (e.g., refineries, chemical industries, etc.) to have access in their required volumes of green hydrogen. Apart from industry, the biggest hydrogen potential, in terms of end-user perspective, is expected to be the transportation sector, and more specifically heavy-duty vehicles and trains.

By 2040, the dedicated hydrogen pipeline could be interconnected with adjacent systems, so that hydrogen can flow from Greece towards South-East, South-West and Central Europe. As TAP will be directly connected with our system, there will be interconnectivity with the Italian transmission system and subsequently with Central Europe, where significant pure hydrogen demand is foreseen. At the same time, the interconnection Greece to North Macedonia, and from there to Kosovo, will be hydrogen ready for future use. Finally, ports in the vicinity of the pipeline, with future import infrastructure for hydrogen (or any forms of it), could also be connected.

Country / Background

Hydrogen infrastructure development

Hungary

FGSZ, Hungary's gas grid operator, operates a mature network of 5,874 km. The network is partially for domestic use, while playing a recently changed transit role from Ukraine to south-eastern Europe. The flows reversed partially and decreased slightly with opening of the LNG terminal on the Croatian island Krk in 2021 and with the gradual opening of the new Balkan routes. Therefore, part of the network might become available at an early stage to be repurposed for green hydrogen transport from Ukraine into the coal-based regions in south-eastern Europe and to the West via Slovenia. Hungary has set a carbon neutrality target for 2050 and targets 6 GW of Solar PV to be installed by 2030. The solar PV potential sits mainly in the south and could lead to variable oversupply of renewable energy, especially if the second nuclear plant in Hungary materialises and operates in parallel with the current nuclear power plant. The current nuclear power plant will be phased out a couple of years after the start of the new plant.

By 2030, changing gas flows open up part of the network to be repurposed for hydrogen transport. This could already mean the repurposing of the interconnector with Ukraine which would connect the Hungarian market to the large hydrogen potential supply from Ukraine. The rest of the network connects several industrial customers in the chemical and fertiliser sector.

If there will be enough hydrogen production by 2035, Hungary could already have a mature - mostly repurposed - hydrogen network with now in total 7 interconnections to Ukraine, Austria, Slovakia, Serbia, Romania , Croatia and a new one with Slovenia. This would connect all Hungary's neighbouring countries and the mostly coal based nations in south-eastern Europe to Ukrainian hydrogen, effectively making Hungary a green hydrogen transit country enabling the decarbonization of heavy industry in south-eastern Europe and the transition away from coal. Interconnections to Slovenia and Austria would already by 2035 connect the energy systems of south-eastern Europe and North-western Europe.

By 2040, the interconnection to Slovenia could increase the market liquidity and security of supply of hydrogen from the direction of the Northern Africa - Italy route.

Ireland

Gas Networks Ireland (GNI) operates a network in Ireland of 2,477 km of transmission pipelines and 12,044 km of distribution and 2 subsea interconnectors from Moffat in Great Britain to just north of Dublin on Ireland's east coast. Ireland has 30GW of offshore wind projects already in the pipeline and plans 5GW[20] of offshore wind to be operational by 2030. Large amounts of intermittent offshore wind production, particularly off the Atlantic west coast could result in electricity grid congestion and curtailment for a country of Irelands' scale. Green hydrogen production and integration with the gas network could provide a way to maximise Irelands wind energy potential, as a store of energy, as an alternative to imported hydrogen and potentially in peak production periods enabling hydrogen export. While scale hydrogen from offshore wind in Ireland is still developing, Ireland could import hydrogen, initially for the power sector providing zero carbon support to intermittent renewables and later for transport, industry and heating. This could be achieved mainly through repurposed existing gas pipeline network, and possibly some new bespoke hydrogen pipelines.

By 2035, a hydrogen "valley" network could emerge around the city of Cork, on Irelands' south coast. Supply resilience for this mainly green hydrogen cluster would be assured with supplementary imported hydrogen which could be either tanker or interconnector sourced (via a hydrogen pipeline direct to the continent). By 2040, one of the 2 Moffat interconnectors from the UK could be converted for 100% hydrogen transport and some relatively small-scale reconfiguration of the Dublin gas transmission network could enable local, scale, hydrogen – fired power generation. The other Moffat interconnector could sustain resilient supply to the remaining unconverted network, it no longer having to serve the Cork cluster and Dublin power generation loads. Development of these dedicated hydrogen networks provide for accommodation of and ready market access for scale green hydrogen and could create the potential for future (through the 2040's) extended gas network conversion to hydrogen, hydrogen consumption for residential heating and industry and ultimately green hydrogen export to Great Britain or beyond.

Country / Background

Hydrogen infrastructure development

Italy

Snam owns and operates the National Transmission System in Italy, with over 32.500 km of transportation network in use and 17 bcm of storage capacity. The Italian guidelines for the national hydrogen strategy foresee that by 2030 hydrogen could make up 2% of Italy's final energy demand. This demand will be mainly concentrated in industrial clusters located in the North and in some areas of the South. The Italian national backbone will connect these clusters with green production facilities in the Centre and South and blue production facilities that may emerge in the North. There is also the possibility of tapping into additional renewable capacity at favourable cost from North Africa. The extended infrastructure will help the country in meeting the target set by the national strategy and deliver green and low carbon hydrogen to industrial clusters in the North of the country (Pianura Padana) and drive the creation of other hydrogen valleys in the South (Sicily, Puglia). Most of these developments will likely happen in conjunction with a switch from fossil sources to hydrogen, thus allowing the use retrofitted existing natural gas pipelines and pivoting on the availability of parallel routes. As the industry scales up and costs fall, the grid will be extended in order to connect with other markets (Austria, Germany, Eastern Europe) and maximize the corridor role Italy may play in supplying Europe with cost-competitive green hydrogen coming from North Africa.

By 2030, The Italian backbone may stretch from Sicily till the hydrogen valley of Emilia Romagna supporting an accelerated development of hydrogen in the country as indicated by the Guidelines on the Italian National Hydrogen Strategy. These developments will be coupled with the potential to import hydrogen from Tunisia, fully exploiting the cost advantage of solar production and land availability in Northern Africa. Most of these developments will consist of repurposed natural gas pipelines as a result of the availability of parallel routes. Hydrogen could potentially be transported both from North Africa and from injection points in Southern Italy to industrial clusters in the South and potentially integrating the blue production in the North that could serve industrial uses in the area. The connection to Austria could allow hydrogen from North Africa to be used in Northern Europe, provided that gas consumption would be gradually replaced by hydrogen and gas security of supply and balancing needs were guaranteed. On the Eastern side, the interconnection to Slovenia connects two large potential supply regions - Ukraine and North Africa. By 2040, an interconnection to Switzerland could be added to provide another connection to North-Western Europe.

Latvia

JSC Conexus Baltic Grid is the national unified natural gas transmission system and storage operator in Latvia, managing 1190 km long gas pipeline connection system which directly connects the Latvian natural gas market with Lithuania, Estonia, and the northwest region of Russia and one of the most modern natural gas storage facilities in Europe - Inčukalns underground gas storage, which is also the only gas storage facility in the Baltic States.

Latvia has not yet developed a hydrogen strategy, there is also no official vision regarding hydrogen development published. National Climate and Energy Plan covering 2021-2030 does not include specific objectives or targets for the production or use of hydrogen, nor hydrogen specific policies and measures. Hydrogen applications are considered as a long-term perspective.

The energy systems of the Baltic states and Finland is already very interconnected, therefore looking at the EHB prom a more area-wide point of view makes most sense.

Current gas system is underutilised. There are some possibilities to potentially repurpose existing gas transmission and storage infrastructure, but also new pipelines will need to be built, to adjust the gas system to higher hydrogen blend or pure hydrogen.

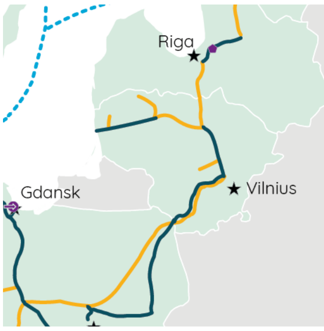
Latvia has an underground natural gas storage (an aquifer), the only gas storage in Baltic States with active gas capacity 2.3 bcm, that could potentially be used in the future for hydrogen storage, after appropriate research and technical adjustments. The gas TSOs of Estonia, Finland, Latvia, and Lithuania in 2021 has already started preparation of research and development study of technical capabilities for injection and transportation of hydrogen in gas grid, study is expected to be finished in 2024 and the results will be used to decide on further hydrogen infrastructure development.

Potentially in the upcoming decade, energy transition projects, such as Power-to-Gas (hydrogen or synthetic methane) could be developed in Latvia, based on hydrogen related national policy framework development. Hydrogen production and infrastructure development could potentially help develop new industries in the future.

Country / Background

Hydrogen infrastructure development

Lithuania



Amber Grid is the operator of the Lithuanian gas transmission system. Company operates 2285 km of high-pressure gas pipelines, gas distribution stations, 2 gas compressor stations. Amber Grid system is connected to gas transmission systems of 4 other countries and the Klaipeda LNG terminal.

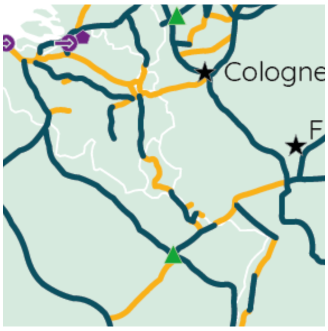
Lithuania's climate change mitigation policy goal until 2050 is to reduce greenhouse gas emissions by at least 80%. Green hydrogen energy will help to balance energy system and replace fossil fuels in the future. Adaptation of gas transportation system and construction of infrastructure for the transportation of pure hydrogen is one of the measures envisaged to enable the transportation of hydrogen from its production sites in the region to consumption sites, both domestically and for import and export in the future. Fertilizer producers, oil refining and transport sectors are expected to be the main consumers of hydrogen in Lithuania.

Lithuania together with the Baltic Region is named as a potential region for the development of surplus wind energy. That creates preconditions for the development of the market of green hydrogen. Adaptation of existing infrastructure and creation of new energy transmission corridors are becoming particularly important. It is expected that the Lithuanian pure hydrogen network, will mostly consist of natural gas pipelines adapted for the transportation of hydrogen. This infrastructure will stimulate the development of RES hydrogen production capacity.

According to the forecasts of the Ministry of Energy, Lithuania's renewable electricity generation capacity will significantly increase in 2025, exceeding the peak demand of the country (2500 MW). The capacity of onshore wind farms will reach 1800 MW, solar power will reach 1000 MW and offshore wind power will reach 700 MW in 2028. These renewable electricity capacities will even be doubled by 2030. Part of the surplus renewable electricity will be used for production of pure hydrogen and will enable development of the pure hydrogen grid.

As of 2030 a demand for hydrogen is expected in the Lithuanian fertilizer production sector. Main consumption will take place in the central part of the country, where the hydrogen grid will be built (or adapted) first. Later, it is planned to connect the oil refinery in the north-west of Lithuania. Also, it is planned to connect the western and central hydrogen corridors of the country, as well as to connect the hydrogen networks with Latvian and Polish hydrogen networks, creating a regional hydrogen corridor connecting Finnish, Estonian, Latvian, Lithuanian and Polish grids.

Luxembourg



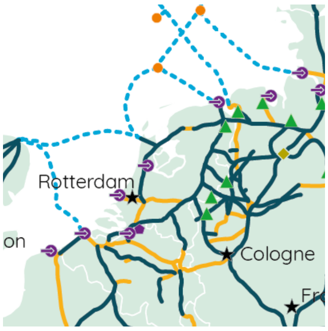
Creos Luxembourg, an electricity and gas transmission and distribution system operator, operates a gas network of 2.175 km with interconnections to the Belgian, French and German gas system. The Luxembourg gas network supplies industrial customers located mainly in the south of Luxembourg as well as residential customers.

In the longer term, apart from the expected development of hydrogen demand in Luxembourg mainly for the needs of industry, transport and the heating sector, Luxembourg could also serve as transit country for hydrogen and thus accelerate the decarbonization of the energy sector.

In the medium term, priority is put on the potential hydrogen supply of industrial clusters connected to a cross-border hydrogen infrastructure.

By 2040 a full connection to the European hydrogen backbone via Belgium and Germany can be envisaged, requiring a new pipeline between the Belgian and German hydrogen networks at Bras respectively to the MosaHyc project near Remich. Another option might be the repurposing of an existing pipeline if the operation of an existing gas interconnection would no longer be justified for the supply of existing gas customers. The Luxembourgish hydrogen network could potentially be used for transit flows.

Netherlands



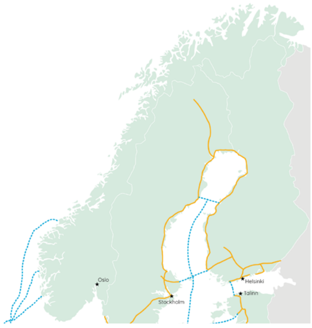
In the Netherlands, infrastructure company Gasunie operates and owns a gas network of approximately 11,700 kilometres. On June 2021 Gasunie received a formal mandate from the Ministry of Economic Affairs and Climate Policy to develop a national hydrogen transport network; the 'Dutch hydrogen backbone'. The accompanying Hyway27 study showed that this network will consist of mostly repurposed existing gas pipelines as these become available due to declining demand for natural gas. This backbone could be in place as early as 2027. The Ministry of Economic Affairs and Climate Policy is currently analysing the exact roll-out (phasing) of the backbone. Thanks to this hydrogen infrastructure, the Netherlands and northern Germany can be the market leaders in Europe for the global hydrogen market, just as they are now for natural gas. This hydrogen 'backbone' connects the five large industrial hubs with each other, with storage and with import/export options. This will enable major companies to wean themselves off natural gas, massively reduce their carbon footprint and maintain jobs, their export strength and innovation capacity for the Dutch economy.

By making maximum use of the existing natural gas transport infrastructure, the national hydrogen backbone can have a capacity of approximately 10-15GW by 2030. The national hydrogen transport network will be developed in phases, following and facilitating the hydrogen market development. The aim is to connect the Rotterdam-Rijnmond region with the area 'Noordzeekanaalgebied' (steel-production) and the Northern Netherlands first. With this first step, these regions will also gain access to underground hydrogen storage at Zuidwending and to Germany. The Schelde-Delta region, including a connection with Belgium, will also be developed at an early stage, but might be able to function as a stand-alone cluster in the first year after development. The connection of the Schelde-Delta region to the other aforementioned clusters will follow next, after which the network-connection towards and in the province of Limburg will be developed. The "ring" will be completed by 2030, but Gasunie emphasises that connections to storage and neighbouring countries for all clusters are possible at an earlier stage (2027). Moreover, Gasunie is investigating the connection of industries that are not situated in one of the major industrial clusters. Gasunie and partners will also be working together to develop the ACE ammonia import terminal. The terminal will operate on the Maasvlakte near Rotterdam and will include an installation for converting ammonia into hydrogen to supply future Northwestern European hydrogen demand. It will also supply ammonia directly to amongst others the fertiliser industry. Work on the basic design of the import terminal will start in Q2 2022, and it will be operational from 2026, connecting to the 'Dutch hydrogen backbone' that can serve the future hydrogen market in Northwestern Europe. Furthermore, by mutually aligning plans for hydrogen transport and storage, joint Dutch and northern German hydrogen infrastructure is very much a possibility, for example the Hyperlink project in Germany. Gasunie is also involved in the German offshore hydrogen infrastructure initiative AquaVentus, which aims to construct Germany's first offshore hydrogen backbone in the North Sea, with possibilities to connect to Dutch, Danish and Norwegian hydrogen infrastructure. Additionally, renewable hydrogen will be used to integrate large amounts of offshore wind energy, particularly in the north of the Netherlands and Germany. More than 180 GWs of offshore wind will be built by 2050 in the North Sea, which will create challenges to integrate this into the energy system. This integration can be economically done by an internationally coordinated development plan of energy hubs, including off- and onshore 'power to hydrogen', as well as system integration between the power- and hydrogen network. A vital role is foreseen for hydrogen to integrate the large amounts of energy into the system and provide seasonal storage. This hydrogen network is also expected to become crucial to stabilise the power grid with new hydrogen fired power plants.

Country / Background

Hydrogen infrastructure development

Norway



Gassco is the independent system operator (ISO) for the integrated system for transporting gas from the Norwegian continental shelf to other European countries. This gas transport system consists of 9000 km of subsea pipelines, 3 gas processing plants in Norway, offshore platforms and receiving terminals in the UK, France, Belgium and Germany. Gassco's operatorship confers overall responsibility for running the infrastructure on behalf of the owners to ensure safe and efficient gas transport to millions of people. Gassco is also the architect for developing the future gas infrastructure on the Norwegian continental shelf.

The pipeline system operated by Gassco transports natural gas from NCS through three large processing plants on the west coast of Norway to Germany, Belgium, France and UK. The potential for hydrogen production from natural gas and from renewable power sources is being studied for all three Norwegian processing plants.

By 2030, Norwegian hydrogen production could be in the order of 2-3 GW, further ramping up to 10-15 GW by 2040. Gassco is investigating export solutions for these production volumes and is assessing development of new dedicated hydrogen pipelines, conversion of existing natural gas pipelines, as well as a combination of new and existing pipelines. Blending of hydrogen into the natural gas export stream is also part of the study work.

In 2030, based on available system capacity, one of the export pipelines downstream the riser platforms Draupner or Sleipner could be repurposed to hydrogen transport. This could for instance be the Europipe pipeline from Draupner to Germany, but the other export pipelines, Zeepipe, Franpipe and Langeled South are also relevant depending on the market for hydrogen. Pipelines upstream Sleipner and Draupner will not be available for dedicated hydrogen transport until after 2035. Transport of pure hydrogen in 2030 would require a combination of existing and new pipelines to establish an export route from Norway to Europe.

A new pipeline, for instance from Norway to the Netherlands, is also an option, however this would have to be sized for volumes expected in 2040. Blending of hydrogen into the natural gas export stream could also be another option to allow usage of the existing natural gas pipelines from 2030.

Green hydrogen from offshore wind energy hubs can complement blue hydrogen supply in 2035, and depleted hydrocarbon reservoirs could become available for hydrogen storage between 2030 and 2040. In 2040, based on current gas market forecasts, another export route from Norway, for instance to Great Britain, could be envisaged by repurposing the Langeled South natural gas pipeline.

Country / Background

Poland

Poland's transmission system operator GAZ-SYSTEM operates a large and increasing network of over 11 000 km of gas pipelines, connecting to Germany, the Czech Republic, Belarus, Ukraine and in the end of 2022 also Denmark, Slovakia and Lithuania, to accelerate the switch from coal to gas, foster competition, market integration and ensure security of supply. Natural gas and its infrastructure will play a pivotal role in the Polish energy transformation by contributing to emission reduction by allowing a switch away from coal. An increase in gas demand is expected until the 2030s. Poland has recently published Polish Hydrogen Strategy aiming for 2 GW of installed electrolyser capacity by 2030. Moreover, the Polish government has also published ambitious offshore wind capacity targets of 5.9 GW by 2030 and 11 GW by 2040. The Polish Hydrogen Strategy indicates the need to build a hydrogen highway, which in its main objectives is to connect the north with the south and the emerging hydrogen valleys. Poland is the third European country in terms of current hydrogen demand (1 million tons), mainly located in the industry in the South plus industrial clusters across the country. A hydrogen backbone in Poland would be crucial to transport energy produced offshore in the North to the demand regions in the South and other consumption centres, while also opening the possibility of green hydrogen imports from Scandinavian wind and decarbonise hard-to-abate heavy industry. Import from other directions such as Ukraine, could be considered, once production ramps up. However, due to the specificity the Polish energy transition, it is important to bear in mind a certain fluidity concerning the timeframes.

Hydrogen infrastructure development

A possible scenario assumes that the initial hydrogen network in Poland will be formed around 2035mainly around offshore wind energy potential in the North and industrial clusters in its vicinity (Pomorskie voivodship), as well as the centre (Kujawsko-Pomorskie and Mazowieckie voivodship). In addition, the potential of an underground storage facility - the Damasławek Project - is expected to be significantly exploited at this time. This storage facility is based on a system of salt caverns and makes it possible to store energy from wind at sea and use it later during periods of low wind speed. This makes it an important alternative to gas or even coal peaker power plants. The Damasławek project will play an important role in linking industrial clusters and planned hydrogen valleys.

In this perspective also a transit connection between Finland and the Baltic States via Poland to Germany may be implemented. This is strictly connected with a pace of H_2 production potential in these countries and the demand level in Germany, as well as ability to create a feasible financing structure (relevant tariff scheme, long term commitments, etc.) for such size infrastructure project. Implementation of this transit connection would allow to integrate the emerging Polish hydrogen network, in particular UGS Damasławek, with the rest of Europe. In case that the very promising forecasts of hydrogen supply from the direction of Finland via the Baltic States would materialize, the construction of a dedicated hydrogen transit link to Germany in parallel to the gas interconnection GIPL (currently under construction) might be justified. Since the Polish Hydrogen Strategy provides for verification of its assumptions in 2025, it will then be possible to make preliminary verification of the dedicated hydrogen interconnection plan with Lithuania assuming a transit connection with Germany in order to enable a transfer of hydrogen from Finland to Germany about 2035.

After 2040, all planned Polish industrial clusters (Hydrogen Valleys) are to be connected, and a north-south connection would complete the integration of large amounts of renewable energy in the north from offshore wind, as well as potential imports from Scandinavia (via Baltic Pipe) and the Baltic States via GIPL that would be repurposed. Additionally, around 2040 there may be a possibility of repurposing a section of the gas pipeline connecting the FSRU in the Gulf of Gdansk with the rest of the planned infrastructure (North-South corridor). This gives flexibility in the form of using hydrogen supplies delivered by sea (with favourable market conditions possible replacement of the Floating Storage Regasification Unit).

The development of the internal H_2 transmission system after 2040 (as well as interconnections), is associated with the forecasted increase of hydrogen consumption in Poland that may lead to becoming a H_2 net consumer. Such market circumstances would create the potential need for repurposing of the interconnections (GIPL, Baltic Pipe) and creating new ones, i.e., Poland – Czechia interconnections. Moreover, the increasing demand for hydrogen in Western Europe, in particular in Germany is expected to be a reason for implementing the second transit infrastructure corridor via Poland, i.e., from Ukraine to Germany. Finally, in the perspective of 2040+, it is possible to create a mature H_2 infrastructure giving the possibility of connecting Poland, additionally, with the Czech Republic, Ukraine and Denmark / Sweden These infrastructure developments would contribute very much to the role of Poland as a real integrator of the regional hydrogen market.

Since repurposing of existing network is not always an option due to increasing demand for natural gas in Poland, technical constraints and the age of existing pipelines, the development of the H_2 transmission system in Poland will consists also of the newly built infrastructure.

It should be noticed that an important factor to consider for a hydrogen network in Poland is the currently growing consumption of natural gas, which will still require a significant portion of the Polish transmission system by 2040. Any repurposing/reconstruction solution will be carefully evaluated on a case-by-case basis due to the technical limitations and heterogeneity of the existing network. The analysis of such potential in the material area has already been started by GAZ-SYSTEM - mapping of the potential, analysis of the transmission system itself and its possible cooperation with hydrogen is underway.

Country / Background

Portugal (REN)

REN - Redes Energéticas Nacionais, owns, under a regulated concession, and operates assets in two major business areas:

– The transmission in very high voltage electricity and overall technical management of the National Electricity System;
– The transmission of high-pressure gas and overall technical management of the National Gas System, the reception, storage and regasification of LNG, at Sines Terminal and the underground storage at Carriço Salt Caverns UGS

Additionally, besides a business area in telecommunications and as ashareholder in some international utilities businesses, REN owns Portgás, which focuses its activity on the development and exploitation of the largest natural gas distribution network in the north coast of Portugal (about 5,493 kilometres).

Regarding the national public policy status, the Portuguese government has developed a national roadmap for Hydrogen (EN-H2) deployment as a key element of the energy transition towards carbon neutrality and focusing on achieving around 2GW of installed capacity, as well as to decarbonise industry and to inject up to 15% of Hydrogen in natural gas system. Additionally, Portugal has published legislation to convert the previous natural gas system to a Gas System, assuming that the assets must accommodate increasingly mixtures of renewable gases and natural gas, converging to the development of 100% Hydrogen system.

At the first stage (until 2030), it is expected that Hydrogen will be transported cross-country in current gas infrastructure, blended with natural gas. Integrated (transmission, compression and storage) dedicated Hydrogen systems (Hydrogen valleys) are also expected to be developed in the main Portuguese industrial clusters, namely in the North (large amount of chemical industry – where is already symbiotic) and in the South (Refinery, chemical and fuels).

Further conversion for 100% Hydrogen of current natural gas grid pipelines will be developed at a later stage depending on H_2 market evolution. The in-between scenario would consist of some areas with a 100% Hydrogen network, while the remaining will have Hydrogen blended with natural gas.

In a future with 100% Hydrogen, a large part of the natural gas network will be repurposed.

Portugal has also a storage potential (salt caverns) at the cross-section of the two main current natural gas backbone lines, which can be scaled up for Hydrogen storage.

Hydrogen infrastructure development

By 2030, at least up to two dedicated industrial clusters (at North and South of the country) could be supplied by dedicated 100% Hydrogen closed loop integrated network systems with a length of around 20 km.

At this stage, REN expects further developments in blending demand to foster the Hydrogen accommodation in gas grid and to promote the decarbonisation of gas system (up to 15% of blended Hydrogen, in 2030 horizon).

From there the next step is to gradually switch the existing network to a fully 100% hydrogen network, coping with the Hydrogen and gas demand in Portugal. Hydrogen and natural gas demand evolution will be critical for this process, as the fully switch from natural gas to Hydrogen, would require adaptation and investments on the utilization side.

From 2035 onwards, it is expected Portugal could receive and share hydrogen, through the northern IP connection to the Spanish Grid, by repurposing the actual gas transmission grid, depending on the development of the Spanish Hydrogen network .

From 2040 onwards, hydrogen import/export would also be possible through the east-west gas repurposed gas pipeline, considering the region existing good renewable hydrogen production potential.

By 2040, it is expected that approximately 40-50% of the grid could be repurposed and operated with 100% Hydrogen.

Country / Background

Hydrogen infrastructure development

Romania

SNTGN Transgaz SA, as the operator of the National Gas Transmission System (NTS) is preoccupied with the potential of integrating hydrogen from renewable and low-carbon sources into the natural gas transmission system in order to comply with the provisions of the applicable European directives and the European Green Deal.

In recent years, hydrogen has become an increasingly attractive candidate for decarbonising the energy sector in line with the EU's climate targets. The EU Hydrogen strategy and the recent draft of Hydrogen and Decarbonised Gas Package set out a new agenda for clean energy investments.

Hydrogen can support the decarbonisation of industry, transport, power generation and buildings across Europe. To ensure that hydrogen is developed to its full potential, there must be a defined perspective towards the development of a well-interconnected European hydrogen market over time.

Large-scale hydrogen consumption will require a well-developed hydrogen transport infrastructure based on a "European Hydrogen Backbone": a vision for a truly European approach, connecting hydrogen demand with supply from North to South and West to East. The proposed Romanian Hydrogen backbone contributes to this purpose.

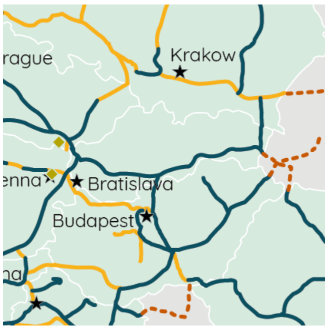
Underlining the importance of establishing a national strategy on hydrogen, a strategy for the implementation of the European Green Deal, in the current European and national context, at SNTGN Transgaz SA level, the sustainable development strategy of the NTS for the coming years requires a resetting of objectives, a reshaping of the development model so that it allows the implementation of the provisions of the Green Deal. Thus, in order to create the "backbone" of the hydrogen transmission system in Romania, the need to repurpose several strategic transmission corridors as shown on the map has been identified.

In this respect, in 2030 Romania can be interconnected with Hungary, Bulgaria via the current BRUA corridor whereas another connection is envisaged with Republic of Moldova in north-eastern Romania.

By 2035, in south-east Romania the Trans Balkan pipeline will stretch from the Ukrainian border to the Bulgarian border, while in north, a hydrogen pipeline will stretch from the existing UA/RO IP to central Romania, insuring in this way potential hydrogen import/export routes. All these pipelines as well as BRUA corridor are interconnected via the central hydrogen backbone.

In western Romania, the interconnection with Serbia is also envisaged for 100 % hydrogen use.

Slovakia



EUSTREAM's transmission system in Slovakia represents an important east-west and north-south energy connection. A robust system of 4 to 5 parallel pipelines is connected to the primary transmission routes in Ukraine, Hungary, Austria and Czech Republic (a new gas interconnector with Poland will be commissioned soon).

Today, Slovakia is mainly a transit country for natural gas. In the future, a similar role is foreseen for large amounts of green hydrogen. EUSTREAM's system lies between the anticipated hydrogen productions centers in the CEE, including Ukraine, and the consumption in Germany and other Western European countries. Its unique geographical position and developed infrastructure makes it well positioned to become an important hydrogen entry gate for European markets.

To connect future markets with production centers, EUSTREAM plans to dedicate one or more of its main transit pipelines only for transport of 100% hydrogen. The modernized corridor of parallel pipelines will allow the combined transport of natural gas and pure hydrogen as soon as there is enough new hydrogen production capacities operational. The large diameter pipelines would provide a cost-efficient way of transporting hydrogen in the east-west direction as well as facilitate hydrogen flows from south further towards Czech Republic and Germany.

By 2030 the Slovak connection between Austria and Czech Republic could be repurposed to supply hydrogen from North Africa further towards consumption centers through interconnection points Baumgarten and Lazhot. By 2035, Eustream intends to repurpose one of its large diameter pipelines from Ukraine in the East to the Austrian and Czech networks in the West. In the beginning with green hydrogen flows still picking up, the lower capacity of hydrogen flowing the repurposed network would also serve the currently coal-based steel industry and chemical industry in Slovakia. Repurposed interconnections to Hungary and Poland would connect another multiple markets and provide higher security of supply as of 2035.

Country / Background

Hydrogen infrastructure development

Slovenia

Plinovodi, the TSO of Slovenia, operates a network of 1,195 km, for domestic use while also playing a transit role from Austria to Croatia and Italy. For both using a doubled main backbone from its capital Ljubljana into the east which then stretches north into GCA's and TAG network in Austria. With the LNG terminal in Croatia on the Krk Island, up and running since the beginning of 2021, the new planned interconnection with Hungary and other changes, the transit role will change. As a result, one of the pipelines of the main backbone could be repurposed for hydrogen. Slovenia has nuclear energy and Solar PV installation is expected to increase. About one third of its electricity comes from coal. The coal fired power plant could be replaced in the future by a gas-fired power plant, thus providing another possible opportunity for the hydrogen. A hydrogen network could be used to serve industry users and power plants with available green hydrogen via Austrian and FGSZ's network or with North African green hydrogen via SNAM's network, as well as from domestic production. While the hydrogen network could also play a transit role, connecting sources of demand and supply, and integrating the energy systems in Italy, Austria, Hungary and Croatia.

By 2035, a regional backbone could emerge. The current main gas pipeline is doubled and together with the changing gas flows due to changes on energy markets, new interconnection with Hungary, and upgrade of connection with Croatia, it enables the repurposing of parallel natural gas pipelines. Thus, the domestic production and consumption can be connected. There would be hydrogen interconnections from Slovenia to Hungary and Italy which connects the national hydrogen markets, but also major green hydrogen supply sources (e.g., North Africa). The connection to Austria and Croatia would ensure that the European Hydrogen Backbone becomes an integrated hydrogen network stretching from South-Eastern to North-Eastern Europe.

Spain

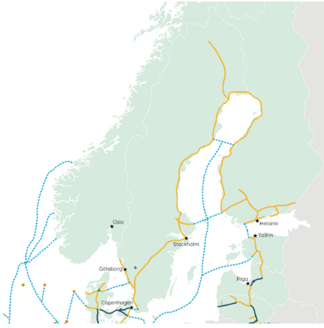
Enagás operates an extensive gas transmission network in Spain that comprises over 11,000 km of gas pipelines. This network has six international connections: two with Africa via Tarifa and Almeria (linking with the Magreb and Medgaz gas pipelines, respectively); two with Portugal via Badajoz and Tuy; and another two with France via Irun and Larrau. The Spanish Hydrogen Roadmap recognises that renewable hydrogen is a key sustainable solution for the decarbonisation and the development of a high value-added green economy. For 2030, the strategy foresees an installed capacity of 4 GW electrolysers and a series of milestones in the industrial, mobility and electricity sectors. The hydrogen pipeline network in Spain is based on a high-level analysis and it would enable the coexistence of both natural gas and hydrogen for a defined period, optimising the use of current infrastructure to serve potential demand in industry and guaranteeing security of supply. At the same time the backbone aims to harness the significant potential of Spain´s solar PV and onshore wind resources, which could enable the exportation of green hydrogen to other European countries. Hereby, also ensuring the role of Spain as a transit country, with pipeline infrastructure to transport low cost hydrogen produced in North Africa to demand centres in Western Europe.

By 2030, industrial clusters within reach of the proposed parallel network and therefore relevant for initial development of the backbone are along the Mediterranean coast and in the center and north of the peninsula. Later, the development of the network will guarantee cohesion between the different demand regions, also integrating the multiple supply points that will be distributed across the geography. Spain's long-term ambition is to be one of the main hydrogen suppliers in Europe, building on its significant large-scale solar PV and wind and hybrid potential to produce green hydrogen. The national backbone will enable this by connecting to France through the existing connections by Larrau (2035) and Irún (2040) and creating a new route through Catalonia by 2040. Connections to North Africa can be made from 2035 to complement supply with imports from the south to cover the demand in Central Europe. With Portugal, it is also planned to repurpose the current connections of Tuy (2035) and Badajoz (2040).

Country / Background

Hydrogen infrastructure development

Sweden



The Swedish climate target is to reach net-zero emissions of greenhouse gases by 2045. To reach this goal, reliable supply, and use of low-cost, green hydrogen in industry and heavy-duty vehicles is pointed out as key enabling solutions, but also as a focus for new industrial initiatives creating innovations, new jobs and export. The national hydrogen strategy, presented by the Swedish Energy Agency in Nov 2021, proposes planning goals of at least 5 GW and 15 GW installed electrolysis capacity by 2030 and 2045, respectively. This alongside with the necessary build-out of renewable electricity production (mainly on/offshore wind parks) and transmission solutions. The creation of a regulation with a revenue framework for hydrogen pipelines is suggested to be in place by 2023.

The visionary and ambitious scenario of a dedicated hydrogen backbone will support and accelerate the targeted decarbonisation and the development of the Swedish hydrogen economy, on the same time as additional robustness to the entire energy system is obtained. The backbone would aid the transmission of energy from north to south creating a sustainable, flexible, and balanced energy system.

During the late 2020s, the Swedish backbone is envisaged to emerge on the coastal regions in the south-west, mid-east and north of the country in the form of regional hydrogen networks connecting hydrogen supply with demand at transforming existing and new established process industries (mining, steel, fertilizer, chemical and/or refinery, e-fuel). Given the absence of parallel methane infrastructure available for repurposing, dedicated hydrogen pipelines will have to be newly built.

Nordion Energi has, together with Gasgrid Finland, started to jointly develop a greenfield cross-border hydrogen infrastructure in the region of Bothnian Bay (Nordic Hydrogen Route, https://nordichydrogenroute.com/) with the target of having the network operational by 2030. At about the same time, as a response to REPowerEU, an offshore hydrogen connection from the Bothnian Bay, across the Baltic Sea with potentially multiple interconnections to the onshore hydrogen networks in Sweden and Finland, to Central Europe is envisioned. The latter strategically located to collect and enable export of potential excess of off-shore wind and green hydrogen production in the area.

By 2035, the southern backbone stretches further north not far from the Stockholm region of Sweden, linking industrial demand centres and cities in southern and central Sweden. Around this time, the southern and northern backbones connect, creating a hydrogen corridor across the country, linking the backbones of Denmark, Sweden, and Finland to the European hydrogen backbone. A new energy transmission network from north to south would in this way be a reality.

By 2040, an additional interconnection (offshore) from Denmark could emerge via the Kattegat Sea area, which would then be the fourth possible interconnector for Sweden.

Switzerland

FluxSwiss markets approximately 90% of the Transitgas pipeline capacity connecting French, German and Italian gas markets. FluxSwiss offers capacity at the three border points Wallbach, Oltingue and Passo Griess. As part of the Fluxys Group, FluxSwiss is ready to participate in building the gas network of the future. Switzerland aims to restructure the Swiss energy system by 2050. To do so a significant increase in using renewable energy and reduction of energy-related CO_2 emissions will be needed. In view of the above a hydrogen strategy will be presented by the Swiss Federal Office of Energy by end of 2022.

A large-scale hydrogen demand post 2030 is expected if the EU wants to honour the Green Deal & Paris Agreement. The Transitgas pipeline links North West Europe to South East Europe and is the shortest route from Italy to NW Europe. It is therefore an ideal partner to ensure the necessary imports from outside Europe and more specifically from North Africa, can reach its destination without capacity constraints on the way. North Africa is considered to be one of the most promising regions for the production of renewable hydrogen.

The exact timing for the development of H_2 transmission infrastructure in Switzerland will mainly depend on the development of the adjacent H_2 markets and the need for import/export between these markets.