Gas for Climate

Priorities for the EU hydrogen legislation

June 2021

GAS FOR CLIMATE
A path to 2050

Table of Contents

1. Introduction

In the transition to a net-zero emission European energy system, Gas for Climate sees a key role for hydrogen[1]. Leveraging Europe's well-connected energy networks, hydrogen can develop to its full potential over the coming years, in a smart combination with renewable electricity and biomethane. Hydrogen is widely acknowledged as an energy carrier that will be crucial to coupling the electricity and gas sector via existing infrastructure, and cost-effectively decarbonising the EU's economy. Besides being an important energy storage medium in supporting the electricity system, hydrogen will also find end uses in hard to decarbonise sectors, such as high-temperature heat for industry and other energy-intensive industrial processes, heavy transport, heating in the residential sector and as a chemical feedstock[2].

Transporting hydrogen through dedicated hydrogen pipelines is a cost-effective way to connect supply and demand across longer distances. This infrastructure will enable the creation of a liquid, pan-European hydrogen market. In the recently published European Hydrogen Backbone maps[3],, a growing dedicated hydrogen pipeline infrastructure is described, developing from an initial 11,600 km in 2030 to almost 40,000 km by 2040 (see Box 1).

For the European Hydrogen Backbone to advance to its full potential, a clear perspective towards developing a liquid and well-functioning European hydrogen market over time is needed. The EC hydrogen strategy[4] sets out an ambitious path towards developing a clean hydrogen industry in Europe, including a target for 2024 of 6 GW renewable hydrogen production capacity, and at least 40 GW by 2030. The roadmap shows that hydrogen will play a key role in meeting the EU Green Deal goal of cutting EU greenhouse gas (GHG) emissions by 55% by 2030, compared to 1990 levels, and become climate-neutral by 2050. The hydrogen strategy highlights the need for enabling an adequate regulatory framework for a liquid hydrogen market with a well-developed infrastructure; however, it does not answer the question of how this new market should be developed and regulated, and what timing should be applied.

Creating the hydrogen backbone requires a regulatory framework that provides clarity to hydrogen market participants, infrastructure companies and investors. The European Commission is expected to propose an EU regulatory framework for hydrogen towards the end of 2021. In this paper, the Gas for Climate consortium explores how the upcoming legislation can help to accelerate the creation of dedicated hydrogen pipeline infrastructure across Europe. The gas Transmission System Operators (TSOs) are ready to play their part in achieving a climate-neutral European energy system by mid-century and to facilitate the cost-effective transport of renewable and low-carbon hydrogen.

[1] Gas for Climate (2019). *The optimal role for gas in a net-zero emissions energy system*. http://www.gasforclimate2050.eu/publications

[2] Gas for Climate (2020). *Gas Decarbonisation Pathways 2020-2050*. http://www.gasforclimate2050.eu/publications

[3] Guidehouse (2021). *Extending the European Hydrogen Backbone: A European Hydrogen Infrastructure Vision Covering 21 Countries.* https://gasforclimate2050.eu/sdm_downloads/extending-the-european-hydrogen-backbone

[4] European Commission (2020). *A hydrogen strategy for a climate-neutral Europe*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0301&from=EN

Box 1

The European Hydrogen Backbone

In April 2021, the European Hydrogen Backbone, a Gas for Climate endorsed initiative, launched an updated plan for a dedicated hydrogen transport infrastructure, showing that existing gas infrastructure can be retrofitted to transport hydrogen at an affordable cost.

The plan foresees a network gradually emerging from the mid-2020s onwards, towards an initial pipeline network by 2030 connecting 'hydrogen valleys'. By 2040, a hydrogen network of almost 40,000km is foreseen, 69% of which will consist of converted natural gas pipelines, connected by new pipeline stretches. The European network can be used for large-scale hydrogen transport over longer distances in an energy-efficient way, also taking into consideration hydrogen imports.

Creating this hydrogen backbone has an estimated investment cost of €43 to €81 billion. The levelised cost of transport is estimated to be between €0.11-0.21 per kg of hydrogen per 1,000 km, allowing hydrogen to be cost-efficiently transported over long distances across Europe. The relatively wide range in the estimate is mainly due to uncertainties in (location-dependent) compressor costs.

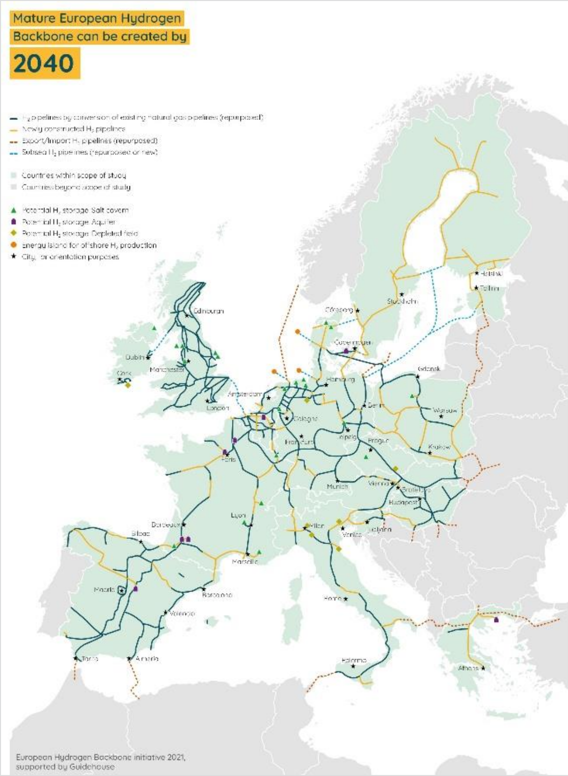


Figure 1 Mature European Hydrogen Backbone in 2040

2. Where do we start

Why is an initial regulatory hydrogen framework needed to kickstart the hydrogen market?

In order to swiftly enable a pan-European hydrogen backbone and market, as well as to kickstart developments and investments, a foundation needs to be laid out by the European Commission as a first step.

This foundation should provide first of all, in the short-term, a clear vision and direction on how the hydrogen market and the associated legislation will develop, combined with an initial hydrogen regulatory framework, setting the first steps towards its future state. A European-wide framework is crucial, as a solely national view will not be sufficient to develop a functioning hydrogen market and network across Member States.

To reach the EU's ambitious climate targets and the desired scale-up of hydrogen, quick action is needed, both in terms of support schemes and in providing regulatory clarity. The creation of an initial hydrogen framework will provide clarity to the hydrogen supply chain and would facilitate investor security. It would allow frontrunner Member States to design their national hydrogen legislation in coherence with the future EU legislative framework. Harmonised EU legislation will enable future compatibility in hydrogen cross-border trade and economies of scale.

What should this initial regulatory framework at least cover?

An initial European framework should aim at enabling the emergence of a dedicated hydrogen infrastructure, facilitating the creation of a uniform harmonised hydrogen market. To this end, regulatory features which will ensure alignment and coordination between Member States need to be established, setting the trajectory towards a functioning internal hydrogen market, and taking into account the increasing integration of the gas and electricity sectors. At the same time, a certain degree of flexibility should be left to Member States as local specificities will require different solutions. According to Gas for Climate, the initial EU hydrogen regulatory framework should cover at least the following elements:

1. Recognising the role of the infrastructure operator in the development of the renewable and low-carbon gas market.

2. Aligning definitions and setting European-wide standards for hydrogen transport and hydrogen grid injection (pure in repurposed or new infrastructure, and blended in existing natural gas infrastructure).

    a. Setting uniform gas quality standards, including the level of pureness and consistency of contaminants;

       These standards should strike the right balance between putting high obligations on all hydrogen suppliers (e.g. removing contaminants after storing) and causing extra costs for hydrogen users with strict quality requirements (e.g. de-ox equipment in the fertiliser industry).

    b. Creating a clear definition of hydrogen as a gas that can be transported and used in a similar way as natural gas;

       Harmonised and uniform terminology, used across Member States, describing the different types of hydrogen, and aligning the classification used such as low-carbon and renewable hydrogen, or different colour indications for hydrogen (grey/blue/green/purple.).

c. Ensuring compatibility of future dedicated hydrogen networks across Member States;

   In order to mitigate future inter-operability constraints, a minimum set of requirements at cross-border points, comparable to the current Network Code for gas interoperability, is needed. By developing a common set of rules, already applicable to unconnected clusters, a harmonised approach early on will be enabled.

d. Implement infrastructure planning rules to incorporate and encourage sector coupling.

   The integration of hydrogen in other energy markets needs to be assured. From early stages, setting the rules for planning European hydrogen infrastructure, considering its integration with the gas and electricity development plans, would ensure efficiency, and avoid the sunk costs of ex-post harmonisation. Being able to plan ahead will allow investing in future-proof solutions, benefiting from economies of scale, and reducing costs. This could also facilitate the development of infrastructure in neighbouring countries that is aligned with the EU regulatory framework early on.

3. Enabling cross-border trade

   The challenges of trading physical renewable and low-carbon hydrogen cross-border, pure or when blended with natural gas in the grid, need to be addressed in the regulatory framework. Trade barriers need to be addressed and dealt with through harmonisation of hydrogen blending to enable cross-border trade.

   Furthermore, the framework should have a specific focus on new and existing infrastructure transporting and trading hydrogen originating from different sources. An EU-wide harmonised Guarantees of Origin (GO) system (see Box 2) is needed to allow for the traceability of hydrogen added to the system from within and outside of the EU.

   Harmonised GOs for hydrogen will allow end-users to buy specific types of hydrogen across the EU, irrespective of their location, thereby enabling cross-border trade. Transferability and consumption of renewable and low-carbon hydrogen will improve the business case and create a market pull. By providing information to consumers, GOs will increase transparency and full disclosure of the energy supply mix.

Box 2

EU-wide Guarantees of Origin for hydrogen

In the EU Renewable Energy Directive (RED II) the Guarantee of Origin (GO) scheme has been expanded to cover not only renewable electricity, but also renewable gases. The GO scheme is a means to prove to the end-consumer that a specific share of the energy it is consuming originates from renewable resources. The GO can be transferred independently from the energetic gas unit it has been initially issued for (Article 19 EU RED II). From 1 July 2021 onwards, the GO systems of all European Internal Market countries should comply with the EN 16325 Standard, facilitating cross-border trade. The standard is currently being revised in order to include renewable energy from all energy carriers.

CertifHy is an industry-driven pilot initiative project to certify renewable and low-carbon hydrogen. Since 2014 the project brought together multiple stakeholders to develop a common European-wide definition of green hydrogen, developing a hydrogen GO scheme deployable across Europe and a roadmap for its implementation. At the end of 2020, CertifHy started the formulation and implementation of a three-year project[5] to harmonise hydrogen GO schemes across Europe and beyond, to build a market for hydrogen GOs in collaboration with market actors, and to design a certification scheme for compliance with RED II renewable fuel obligations.

[5] For the latest information see; https://www.certifhy.eu/

4. Clarity on a gradual regulatory framework on third-party access and a level of unbundling

   Speed and timing are essential to the development of the hydrogen network. A too detailed initial framework might hinder market developments and push back investment decisions. Nevertheless, setting up the basis for a non-discriminatory regulatory framework around third-party access (TPA) on the transmission level infrastructure, and unbundling is essential as hydrogen networks are expected to constitute a natural monopoly in the future and will form an essential facility for society. The increasing size and geographical coverage of the hydrogen infrastructure, combined with a growing number of hydrogen producers and consumers across the EU, will augment the need for regulation according to the market's needs.

   In the initial phase, introducing a hydrogen legislative framework will enable better planning of the hydrogen infrastructure and reduce the risk of distorting the internal energy market, setting rules around objective, transparent and non-discriminatory access. This will enable a well-informed marketplace, providing the regulatory certainty needed for initial investments in the hydrogen value chain.

   TPA rules aim to guarantee objective, transparent, and non-discriminatory access to dedicated hydrogen infrastructure for all market parties. Access could range from regulated third-party access (rTPA) to negotiated third-party access (nTPA). Under a nTPA regime, the TSO and user negotiate the access to the network with terms and conditions published ex-post (or not at all). Under rTPA, gas TSOs are required to provide non-discriminatory access based on published terms and conditions, including tariffs, set or approved by the national regulator.

5. Clarity on the financing of dedicated hydrogen infrastructure.

   Initially, dedicated hydrogen infrastructure (mainly based on repurposed existing natural gas transmission infrastructure) may seem over-dimensioned relative to the nascent hydrogen demand. Repurposed natural gas pipelines with a diameter of 20 to 48 inch can transport 1.2GW to 13 GW of hydrogen. While such capacities will likely be needed in the future to come to the most economical hydrogen pipelines, in many cases, initial hydrogen demand will not be sufficient to guarantee a high utilisation of these pipelines. The few initial hydrogen consumers that require hydrogen pipeline transport cannot be expected to bear the full cost of creating a dedicated European hydrogen infrastructure. This means that a form of financial support will be needed to make these investments bankable. Even in the following stage, when a sufficient but still small number of users will be connected, there will be a substantial risk to the business case if one of them would drop out, leaving this risk with investors, and increasing the cost of capital. Supporting mechanisms should meet the following criteria:

   - Feasibility (manageable level of complexity for investors and administrations)
   - Efficiency (incentive to efficiency/competition in order to maximise societal value)
   - Effectiveness (optimise risk allocation and therefore minimise the cost of capital)
   - Just distributional impact (avoid unnecessary costs and distortive distributional impacts)
   - Consistency with EU and national normative framework (including e.g. State Aid rules, Carbon Border Adjustment Mechanism, EU ETS extension)

   An overview of different financing options seen by Gas for Climate is given in chapter 4.3.

6. Exemptions for hydrogen valleys and private networks

   A clear definition of exemptions and foreseen trajectories and end dates for hydrogen valleys and private networks (for example isolated industrial clusters and point-to-point arrangements) is needed under the upcoming legislative framework.

Under a new legislative framework for hydrogen, full regulation of the infrastructure at such an early stage, might constrain the search for a balanced risk and reward sharing between producers and consumers, and hamper investments or make infrastructure developments uneconomic. Regulatory flexibility at national level, including tripartite discussion between governments, hydrogen infrastructure owners and users, together with NRAs, would enable investments associated with high levels of risks, or developments in geographically limited areas and emerging markets.

7. Ensure coherence between the hydrogen legislative framework and the EU's overall direction for the Energy Transition

   In 2021, several interlinked legislative revisions will take place, including the ETD, IPCEI, TEN-E[6] and, RED III[7]. The EC has a critical role in aligning the hydrogen framework with the EU's ambitions on the energy transition and recovery plans. This implies moving beyond regulation which has worked for the mature, stand-alone electricity and gas sectors and finding ways to encourage sector coupling and foster market development. It is key that the investments towards the European Hydrogen Backbone is unlocked within the above-mentioned revisions, thereby including the development and repurposing of the existing infrastructure to dedicated hydrogen pipelines.

   A more comprehensive set of rules (see Chapter 3), following the initial framework, should be implemented gradually, based on the actual development of the hydrogen market. Nevertheless, a clear vision on the trajectory and on the regulatory framework for hydrogen is needed as soon as possible, to allow hydrogen to take its pivotal role in the European energy system.

[6] Gas for Climate published a policy review on TEN-E in March 2021, which can be found here www.gasforclimate2050.eu/publications

[7] Gas for Climate calls for a binding target for 11% renewable gas by 2030. The policy paper published in January 2021, can be downloaded here; www.gasforclimate2050.eu/publications

3. Where do we go next?

3.1 On a path to full steady-state regulation

The initial hydrogen legislative framework, as described in the previous chapter, will create a solid foundation for the path towards 2030 and beyond. Setting an initial framework prevents over-regulation at the beginning, which would deter participation by first movers and hinder market activity, while providing a clear context for investments in infrastructure. However, in order to fully develop a hydrogen backbone in a functional internal hydrogen market in the longer term, the Gas for Climate consortium foresees in the longer term, a similar level of regulation at EU-level as currently existing for the natural gas infrastructure.

As recognised in the EU hydrogen strategy, a legislative framework from the EC is needed, however regulation for hydrogen should be designed to evolve with the market, supporting its development in size and connected system users. While the current Gas Directive was developed when the gas market was already well-developed and mature, the hydrogen market is still emerging. Therefore, a step-by-step approach will be needed, allowing the EU, Member States, and TSOs to get started with the initial legislative hydrogen framework and ultimately move more quickly as the market evolves. This step-by-step approach would leave Member States flexibility to apply best practices to the local context. Such flexibility is needed to allow for differences in the speed at which hydrogen is scaled-up per country and the relative level of development of local hydrogen markets. Developing a too detailed set of rules from the start would hinder and slow down hydrogen market development.

The step-by-step approach should make clear from the beginning when, and under which conditions, the various steps of the regulation of the network will kick in, based on certain market indicators and concise rules. The gradual shift from the initial hydrogen framework to the envisioned full steady-state regulation, should be in line with the actual development of the hydrogen infrastructure, system users and market developments. Several options exist for how this gradual shift could take place;

- A "market maturity" approach, where the gradual shift is triggered by market conditions. This approach leaves room for the variation of hydrogen market development in the EU Member States.
    - Regulation could specify a timeline to review exemptions for point-to-point networks and then at that time look at the market conditions and grant (or not) an extension of the exemptions.
    - Regular monitoring and market tests at a national level, as advised by ACER and CEER, could be an appropriate way to assess the market circumstances to identify the need for further legislation and by when this would be needed.[8].

- A "timeline" approach, where the gradual shift is triggered by a predefined timeline. This would prevent unclear market characteristics that are defined and interpreted differently between Member States.
    - Private networks would benefit from a clear timeline, allowing them to set up time-based agreements accordingly and with a firm deadline to guide contracts.

[8] ACER, CEER (2021). *When and how to regulate hydrogen networks?* Accessed on 12 February 2021. https://www.acer.europa.eu/Official_documents/Position_Papers/Position%20papers/ACER_CEER_WhitePaper_on_the_regulation_of_hydrogen_networks_2020-02-09_FINAL.pdf

3.2 What does full regulation look like?

Gas for Climate envisions a liquid hydrogen market to develop in the future. A financially liquid market, easily accessible to many producers and consumers, possesses a high level of stability, and low spreads between asking and selling prices. A high enough hydrogen trading volume exists, with sufficient numbers of market participants, to create a stable market.

For the functional internal hydrogen gas market to develop, at least the following three conditions[9] must all be met simultaneously:

1) Free and non-discriminatory access to the hydrogen backbone infrastructure for producers and consumers,

2) Free and fair competition among suppliers, and

3) The ability for consumers to choose freely between suppliers.

Similar to the foundations of the Gas Directive, a mature hydrogen network will be an essential facility (access is deemed necessary for effective competition), and it will need to be regulated with the basic provision of TPA, unbundling and regulated tariffs, in order to develop a competitive hydrogen market. Gas for Climate sees that regulated tariffs and TPA are part of a future when the TSO will be acting as an unbundled regulated monopoly in a mature market.

The development of a European hydrogen backbone in line with the vision set out by the Commission, would not be possible without TPA. Hydrogen infrastructure will exhibit monopolistic features when the backbone grows. In the cases where infrastructure is paid for by public funds, the risk is taken by citizens and society, and regulated non-discriminatory access to that infrastructure might follow. Therefore, in the case of dedicated hydrogen infrastructure exhibiting monopolistic features, these should be operated based on TPA, covering both new and repurposed pipelines. Market characteristics that would make TPA regulation necessary include market failures in supply and demand and benefits of economies of scale, resulting in the risk of high consumer charges unless infrastructure development is managed efficiently. In particular, when distances are large between producers and users of hydrogen, TPA is needed to efficiently pool and ensure logistics between supply and consumption areas. In a liquid mature hydrogen market, regulated TPA seems the fitting choice, similar to the current natural gas market. Finally, to optimise TSO efficiency and societal welfare, it seems possible to enable a progressive conversion of the existing gas network to hydrogen, minimising the cost to society versus starting hydrogen pipeline development 'from scratch'.

Connected to TPA is unbundling. Unbundling aims to partially or totally separate between the monopolistic (regulated) and contestable (non-regulated) activities. Vertical unbundling, not necessarily implying ownership unbundling, separates transport, distribution, production and supply activities. Vertical unbundling is needed to create a well-functioning internal hydrogen market where connection and access to a network are non-discriminatory, insofar the market takes the features of a natural monopoly. In the current natural gas market, different models of unbundling exist in and between Member States. As there is no developed hydrogen market and no competition, a certain level of unbundling is enough, in order to take into account the need to promote investment and innovation in the kick-off phase. Gas TSOs see a role for themselves in the planning, investment, and operating of future hydrogen networks. This will enable the repurposing and retrofitting of existing gas infrastructure and stimulate integrated planning of natural gas/biomethane infrastructure and hydrogen infrastructure, while building on existing experience and knowledge within the Gas TSOs. Once TPA and unbundling regulations are in place, regulated tariffs come next. Dedicated hydrogen infrastructure in a liquid market is therefore likely to be operated under a regime of regulated tariffs.

[9] A.R. Spanjer (2008). Structural and regulatory reform of the European natural gas market. https://scholarlypublications.universiteitleiden.nl/access/item%3A2896126/view

4. Financing the 2030 European Hydrogen Backbone

The proposed European Hydrogen Backbone 2030 network of 11,600 km (see Figure 2) is a necessary and urgent step in the creation of a pan-European hydrogen infrastructure. It can be created if both network and investment planning start within the next couple of years. This section explores the investment needs of the 2030 Backbone for the Gas for Climate countries, using the EHB cost assumptions, and subsequently explores options to fund these investments. We will refer to all such options as 'financing' throughout this chapter. Financing, and the cost at which this can become available, depends on the projected income flows for the infrastructure, and the level of certainty with which those materialise. Options to enable financing of a hydrogen infrastructure include EU-level regulation and market-driven options. The various options are presented here alongside each other without a clear preference. The choice of the preferred option depends heavily on national contexts and likely differs across EU Member States. The analysis below focuses on nine EU Member States whose gas TSOs are represented in Gas for Climate. This means that not the full 2030 EHB (including the UK) is represented in this paper.

4.1 Investment needs

By 2030, the European Hydrogen Backbone largely consists of several separated networks. These regional backbones consist of mostly repurposed natural gas pipelines, with the exception of Greece and Sweden which both have a limited natural gas network today. The total length of the hydrogen networks in the nine countries in Table 1 already amounts to over 9,100 kilometres, of which over 64% consist of repurposed natural gas pipelines. It should be noted that the April 2021 EHB maps did not include a 2030 backbone for Greece. However, since then the ambitious 8 billion Euro White Dragon[10] IPCEI project has been announced, which foresees a new dedicated pipeline to connect the potential production sites with Athens and Corinth industrial areas, Thessaloniki, Kavala and potentially other neighbouring systems.

Table 1: Hydrogen backbone lengths per country in 2030

Country	New dedicated hydrogen pipelines (in km)	Repurposed natural gas pipelines (in km)	Total length of national backbone (in km)
Belgium	230	410	640
Denmark	200	0	200
France	380	250	630
Germany	210	1,270	1,480
Greece	670	0	670
Italy	530	1,220	1,750
Netherlands	202	981	1,183
Spain	0	1,520	1,520
Sweden	1,040	0	1,040
Total	3462	5651	9113

[10] 8 Billion Euro Greek Hydrogen Plan "White Dragon" Set For take-off (2021). https://fuelcellsworks.com/news/8-billion-euro-greek-hydrogen-plan-white-dragon-set-for-take-off/

The investment for the 9 countries considered were calculated based on the EHB assumptions. For 2030, the investment needs were calculated only taking into account the costs for hydrogen pipelines, excluding compression costs. This leads to an investment need for 2030 of around €11 billion for the nine countries represented in this paper.[11]

These investment needs show the relatively modest investment (compared to investments needed on the demand and supply side) needed to start up hydrogen infrastructure developments in Europe, providing the important first step towards a pan-European liquid hydrogen market. Further research into the costs of creating the 2030 national backbones will be needed to obtain an improved insight.

Investment cost per country are expected to differ, due to the diameter of the pipeline as well as the length and the share of new versus repurposed pipelines. It should be noted that these larger pipelines will be able to handle significantly higher throughput of hydrogen. See Appendix A. for the assumptions regarding the throughput and cost assumptions for each pipeline scenario. As in the EHB analysis report, the capacities for some pipeline scenarios were set below their maximum to minimise the levelised cost of hydrogen transport. The same cost assumptions were then applied to the lengths of each type of pipeline determined by the TSOs during the mapping process to arrive at a rough estimate of the required investment costs.

[11] The EHB assumptions on compression needs for 2040 are applied linearly based on calculations for 1,000 km of hydrogen transport as presented in the EHB paper. In reality, compression needs decrease strongly with distance travelled. By 2030, in the regional backbones, hydrogen would likely travel distances well below 1,000 km, and the inlet pressure could provide a significant part of the required pressure difference. Therefore, investment needs for compressors are expected to be non-existent or at least significantly lower compared to the mature, pan-European backbone by 2040.

4.2 Investors perspective on hydrogen financing

To develop the European Hydrogen Backbone a significant investment is required over the coming years to repurpose and build the required infrastructure. The required investment volumes will need both access to funding on this scale from the market and a professional financing approach. Multiple interviews with financial institutions were carried out to describe investors' perspective on financing the hydrogen backbone and to identify the key challenges. The interviewed investors are all not new to the field of energy infrastructure financing but are currently not yet involved (or on a very small scale) in hydrogen projects or companies.

We spoke with the following financial institutions, which either invest in (listed) companies, provide bank loans, and or project financing: Marshall Wace, Magellan Group, ABN AMRO, Robeco SAM, GIC, KfW. Their investment horizons range from 3 to 15+ years.

A significant interest in hydrogen and hydrogen infrastructure is perceived from all interviewed investors, stating that they see a potential major role for hydrogen in the future energy system, and see a lot of potential for dedicated hydrogen networks. A close eye is being kept on the developments in the sector. One of the driving factors for this interest is that climate change is happening and will only become more problematic, therefore long-term solutions towards a net-zero energy system are needed and here to stay. This notion is lowering the investors risk. One of the investors indicated that it is even seen as a red flag when companies do little on hydrogen if they could benefit from developments in the field.

Key challenges

Multiple financing challenges and potential risks for hydrogen infrastructure projects were described by the investors. The most important ones are:

- *Regulatory challenges*: Investors in the corporate financing field indicate that regulatory issues are one of the most important factors influencing their investment decisions. A political decision to actively start taking steps toward a hydrogen market in Europe would be needed, providing a reliable and transparent regulatory framework.

- *Economic model:* The rate of return needs to be attractive enough for the investor. With the security that the cashflow of the company will be enough each year to service the debt. Subsidies can mitigate this risk and create incentive for investments.

- *Political & country risk:* The current political landscape is deemed favourable for the employment of hydrogen. However, national political parties who do not see the energy transition as a priority and that are less in favour of renewables, are seen as country specific risks. Furthermore, the transparency and predictability of the decision making of national government and regulators are considered by investors when making their investment decisions. At the EU-level, investors indicate that a harmonised approach between Europe and neighbouring countries, such as the UK and Norway, would be favourable.

- *Supply & demand risk:* As the market for hydrogen is not yet developed, the viability and potential variability is being perceived as a risk for the development of hydrogen infrastructure, as stranded assets should be avoided.

- *Technology risk:* Every new technology has its risks, the risks for hydrogen infrastructure are not deemed substantial but are taken into account. Potential leakage and the perception of the public are for example factors that are considered.

Repurposed and new infrastructure

There is no real difference perceived between financing repurposed or new infrastructure with regards to corporate finance approach, as the infrastructure operator is able to diversify the risk of the project in a broader portfolio. However, on the level of project financing the construction phase poses a significant risk. During the construction phase of a project capital expenditure is required, however remuneration only begins when the project becomes operational. Investors indicate that they have the experience that it is hard to deliver projects on time and on budget. These cost overruns and potential delays to the start of the operation are perceived as risks. These risks can be mitigated with a cost-overrun allowance, or special adaptations to regulatory models (such as buffers) and government involvement.

A gradual approach to regulation

A flexible and gradual approach on regulation is not seen as unfavourable by most investors. More important is to get the process going in order to get the market started. For most other regulated assets, regulation also changes over the years, this is a known regulatory risk that investors are willing to take. When investing into existing gas TSOs who would incrementally repurpose their national natural gas networks to hydrogen, these assets would still fall under the same regulated business, therefore not creating a risk for the investor.

Closing remarks

Financial institutions are happy to follow innovative developments in the energy transition and urge companies to present their projects (ideas) to them as soon as possible. This allows their internal organisation to learn and develop, in order to be able to move with their clients when the time is there. National governments can play an in important role in establishing the hydrogen backbone, investors urge them to set clear targets and timelines, to implement policies to meet those, to invest funds in their hydrogen clusters and to get the hydrogen market going. The bigger the market will become, the easier financing will be.

4.3 The financing option landscape

Analysing each Gas for Climate country's state of play shows that each Member State has different national specificities and starting points with regards to gas and hydrogen infrastructure. For example;

- The extent of existing gas infrastructure and repurposing options,
- Expected demand and supply of hydrogen on a national level,
- The extent of overlap between current natural gas users and future hydrogen users
- Specific national regulations.

In view of these differences between countries, Gas for Climate sees different options to finance in an efficient way the investments needed for the 2030 European Hydrogen Backbone. This chapter will further elaborate on these options in a mixed financing system.

The main sources of financing energy infrastructure investments today are equity and debt. Sources on the debt-side are for example international financing institutions, commercial banks and corporate bonds. On the equity side, sources stem from internal equity from the TSO's cashflows and external equity from investors. Equity from the TSO's cashflows is usually not sufficient to deliver the funding needs for major investments. Therefore, investments in the shape of equity or debts are needed. The amount of investments up to 2030, as described in Chapter 4.1, will require a significant sum of investments into the development of hydrogen infrastructure. Access to capital is a key factor to ensure the financing of these future projects.

The primary source of revenues for owners/operators of infrastructure consist of revenue streams in the form of charges, such as tariffs, paid by the end-users. Next to this, public funds can be used as well. Clear return on investments and predictable cash flows are key factors in attracting investors to finance energy infrastructure. Regulatory challenges are identified as one of the most important factors in the financing of energy infrastructure (see chapter 4.3). For both the TSO planning the investment and the financing institution providing the funds, a transparent, reliable and attractive (in terms of return) regulatory framework is needed.

Options to enable financing of the 2030 European Hydrogen Backbone

Gas for Climate envisages several different options to finance the 2030 European Hydrogen Backbone. The various options are presented here alongside each other without an overall preference. The choice of the preferred option(s) depends heavily on national contexts and likely differs across EU Member States.

In the long run, all Gas for Climate members see the need for a **regulated assets base (RAB)-based system**. In this business model, projects are approved by the NRA and become part of the RAB. These projects are then most commonly financed through corporate financing. The repayment of investment expenses for these projects happens through regulated revenues, meaning that the project costs are regulated and directly "socialised" by consumers paying via a share of the tariffs for new and repurposed hydrogen infrastructure.

The tariffs up to 2030 can be established in multiple ways:

- Separate, cost reflective tariffs for hydrogen infrastructure would require consideration of long-term costs and benefits of these systems. A hydrogen tariff should not lead to penalising early users of the dedicated hydrogen infrastructure for contributing to the decarbonisation goals of their demand sector. Furthermore, early users will enable system build-up and provide important learnings to the sector, enabling cost-reductions in the long term. Mechanisms to recover investments in a cost-reflective manner could for example be long depreciation periods to not disproportionately burden the initial hydrogen infrastructure users.

- To enable the development of hydrogen infrastructure and to cope with possible initial underutilisation of hydrogen infrastructure it should be explored to what extent the methane tariff income from TSO's could be used to pick-up part of these costs. This approach could be useable in countries where there will be a significant overlap of methane users today and the hydrogen users in the future. It should be noted however that not all of today's natural gas customers will necessarily use hydrogen in the future. In addition, as hydrogen infrastructure offers benefits for the total energy system it could also be envisaged that all energy system users would contribute to the cost of creating hydrogen infrastructure (transport and storage).

Another option is to finance hydrogen infrastructure on a project specific level. **Project financing** requires an independent project company and the acquisition of separate equity and debt and the subsequent management of this capital. Long-term offtake agreements or bringing the project under a RAB based system would be required to minimise the risk for investors.

Combined with both approaches within the RAB-based model, hydrogen infrastructure projects can be sponsored via **grants** to reduce the required equity financing amounts. As such, grants can reduce transmission tariffs, as the share of the investment now covered by the grant will not be reflected in the tariffs for the consumer. Besides reducing transmission tariffs, supporting hydrogen infrastructure projects via grants can cover risks relating to the advance capacity challenge and create incentives for investments. Many hydrogen backbone projects will face advance capacity challenges, where the viability of investments depends on future supply and throughput. These projects would need to be supported so that greater capacity can be planned, built, and financed even though full utilisation may only be achieved at a later point in time. Building infrastructure capable of handling more capacity than exists at present is cheaper than upgrading such facilities in the future. Government funding could take the shape of funding the entire project at the outset through an upfront CAPEX subsidy or facilitating an incremental approach through a TOTEX subsidy with an upfront guarantee for the total amount that could be needed. On an EU-level funding instruments such as Trans-European Networks for Energy (TEN-E) grants, Connecting Europe Facility (CEF) and Important Projects of Common European Interest (IPCEI) could play an important role.

Harmonisation across the EU

Leaving flexibilities for national approaches will contribute to create the optimal investment landscape for the specific situation and starting point of each country. However, it is important to note that a level of harmonisation across the EU will be needed to increase the transparency and comparability for investors and enable a level playing field. Harmonisation could be achieved by aligning from the start across Member States on investment approval processes, and use the same financial indicators in handling and steering of investment projects in order to be able to compare between countries.

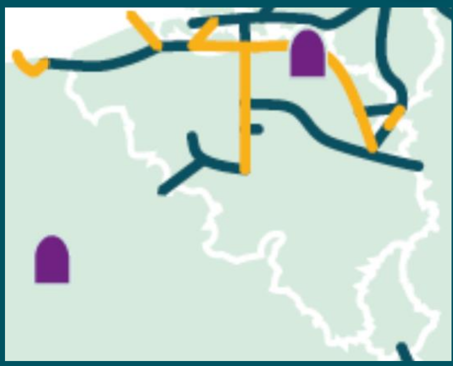
4.4 Bridging the gap: National perspectives on hydrogen infrastructure and financing

Each Gas for Climate country has a different starting position and national viewpoint when it comes to the development of the European Hydrogen Backbone. The analysis in this chapter zooms in on a country-level, giving a view on the development of national hydrogen backbones. Taking into account the national context, current developments, political setting and specific country-level barriers and opportunities. Each country perspective answers the main question; How does the financing of the 2030 EHB backbone look on a national level? And to what extent does regulation play a role in the development of hydrogen infrastructure up to 2030?

Figure 2 The European Hydrogen Backbone in the Gas for Climate countries

4.4.1 Belgium

Belgium could have a hydrogen backbone of 640 km in 2030, consisting of 64% repurposed pipelines and 36% new dedicated hydrogen pipelines. The Belgian national backbone is expected to emerge through developments in and around the industrial clusters in Antwerp, 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 could provide Belgium access to hydrogen from/to neighbouring countries.



Hydrogen backbone length in 2030
New: 230 km
Repurposed: 410 km

Political context The Flanders, Wallonia and Brussels already published their hydrogen strategy. A hydrogen strategy will be published soon by the Belgian federal government, followed by a consultation on the principles of a regulatory framework for hydrogen, covering amongst others a unique and neutral TSO, open third-party access, and transparency.

Ongoing projects There is already a private hydrogen pipeline network in Belgium, which is owned and operated by Air Liquide. The network connects its own production and customers. This network is connected to France and the Netherlands.

Fluxys, the Belgian gas TSO, has plans for a national hydrogen backbone in line with European objectives. Fluxys submitted an IPCEI project and a request for support for the Belgian hydrogen backbone under the Recovery and Resilience Facility (RRF).

Furthermore, Fluxys has started a Request for Interest (RFI) process in January 2021 to identify potential suppliers and consumers of hydrogen. To date, 90 market participants provided responses for 155 sites across Belgium. Fluxys is currently assessing the results in order to propose the first infrastructure developments later in 2021.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure Barriers perceived by Fluxys are the lack of a positive business plan; lack of clear legal and regulatory framework, lack of cash flow during early stages of hydrogen market development (when the costs will be higher than the revenues as tariffs should be low enough to foster early developments), lack of concrete technology solutions and costs for repurposing.

Financing options in Belgium Fluxys group would carry out the hydrogen investments, supported by debt. Hydrogen investments could impact the company's risk profile. A conductive regulatory regime and adequate capital support schemes, such as grants and cross-subsidisation, would be the most effective instruments to support the early development of hydrogen and to decrease the risk of hydrogen developments and therefore the cost of capital.

Other opportunities around financing perceived by Fluxys would be to have national targets for hydrogen production and/or consumption, grants for investments, advanced payments to improve cash flows and European-led negotiations for to secure imports of hydrogen instead of national-led initiatives.

4.4.2 Denmark

Hydrogen backbone length in 2030
New: 200 km
Repurposed: 0 km

In 2030, Denmark could have a hydrogen backbone of 100-200 km. The initial development of the Danish backbone in 2030 could consist of constructing new pipelines, and at a later stage repurposing parts of the existing natural gas network to export hydrogen from Denmark to Germany and/or to connect hydrogen producers and industrial clusters with large-scale storage facilities. In 2040, the total Danish hydrogen backbone could cover most of the country with interconnectors to Sweden, Germany, and Poland.

Denmark has an abundance of renewable energy sources, particularly offshore wind, which can be utilized for production of green hydrogen. Demand for hydrogen is, however, relatively limited in Denmark. Thus, Denmark could become a net-exporter of hydrogen – in particular to Germany where hydrogen demand will probably be much higher than the targets for renewable hydrogen production in Germany.

Political context The danish government will publish a joined Power-to-X and CCU/CCS strategy at the end of 2021. In relation to the strategy, initial discussions on general principles of the hydrogen regulation have started. The conversation on financing options for hydrogen infrastructure is still in the early days as no concrete projects have materialized.

Ongoing projects Currently, Energinet is not involved in any hydrogen infrastructure projects as the legal mandate for hydrogen activities is yet to be clarified. Power-to-X is viewed as an important part of the offshore wind development in Denmark. Energinet is looking into how hydrogen infrastructure can contribute to the integration of more renewable energy and potentially place Denmark as a net-exporter of hydrogen. Energinet sees growing interest in hydrogen infrastructure for large scale transport and storage from project developers. In the last year project visions for 2030 with a combined electrolyser capacity of over 4GW have been announced in Denmark. Infrastructure needs are still very uncertain, but connection to a hydrogen cavern storage or the possibility to export hydrogen to the German market seems as the most viable options in the initial phase of market development.

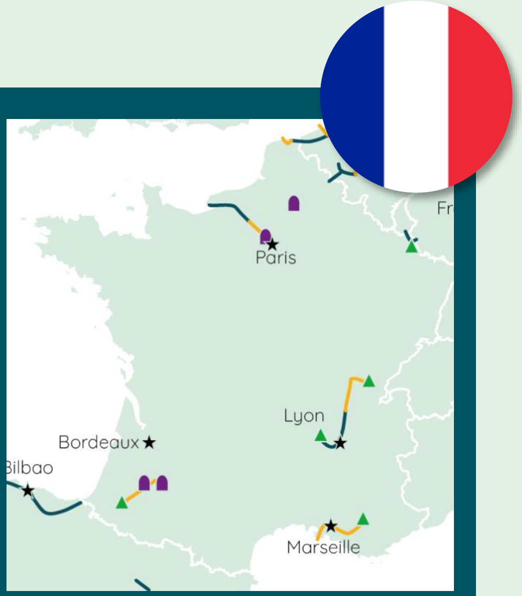
Perceived opportunities and barriers to invest and develop hydrogen infrastructure The main barriers identified by Energinet include the current low hydrogen demand and supply which give little incentive to invest in infrastructure. Besides this, the lack of clarity regarding regulation and the role of the gas-TSO in the hydrogen market should be addressed.

Financing options in Denmark Financing hydrogen infrastructure is still discussed at a theoretical level. The chicken and egg paradox is evident. Energinet does not view cross-subsidisation between gas and hydrogen as a viable option in Denmark. Gas demand is falling rapidly in the country, and there is a very limited overlap between current gas consumers and future hydrogen consumers. That being said a traditional RAB-based approach is not deemed to be sufficient to ensure financing in the initial phase of the hydrogen market development. It will be difficult to ensure sufficient volume at first and shippers will probably not be willing to go into long term contracts due to the uncertainties in a immature market. Alternative forms of financing have to be identified and evaluated in view of the specific circumstances in Denmark.

4.4.3 France

France could have a hydrogen backbone of 630 km in 2030, consisting of 40 % repurposed pipelines and 60 % new dedicated hydrogen pipelines. Regional dedicated hydrogen networks will emerge around industrial clusters, with now 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 develop at the border between France, Germany, and Luxemburg with the commissioning of the mosaHYc project. The southern clusters in Marseille-Fos and Lacq are also expected to have access to green hydrogen from solar PV and Mediterranean offshore wind. In the region around Lyon, the 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.



Hydrogen backbone length in 2030
New: 380 km
Repurposed: 250 km

France can take an important role in the transit of hydrogen on a European scale, connecting a strong hydrogen demand in Northwest Europe (Belgium, the Netherlands, and Germany) with a competitive and abundant supply on the Iberian Peninsula and North Africa.

Political context France published its hydrogen strategy in September 2020. The strategy sees three priority areas: mobility, electrolysis and industry decarbonation with a view to 2030. The vision has now been expanded from 2030 up to 2050. Discussions on hydrogen regulation with the French authorities are still preliminary as the French regulator does not have any legal competency on hydrogen yet. The investments approved in the natural gas transport tariffs concern assessments of the injection of hydrogen in R&D projects.

In 2020, discussions mainly focussed on the injection of hydrogen into the gas networks. The ordinance on hydrogen (published in February 2021) authorises the injection of hydrogen into the gas networks, defines different categories of hydrogen and introduces a guarantee of origins system. Modalities and technical prescriptions on the injection of hydrogen are still under discussion with the government.

Ongoing projects The French gas TSOs Teréga, serving the south-west quarter of France, and GRTgaz, covering the rest of France, are committed to hydrogen development through several infrastructure projects. Teréga projects include; Lacq Hydrogen, which will study the production and supply of renewable hydrogen between France and Spain, and the HyGéo project, studying storage in an underground salt cavern. Other hydrogen development activities include quantifying potential impact of hydrogen in underground storages (aquifer) currently operated for natural gas. These feasibility studies for hydrogen projects are financed today by Teréga on equity capital.

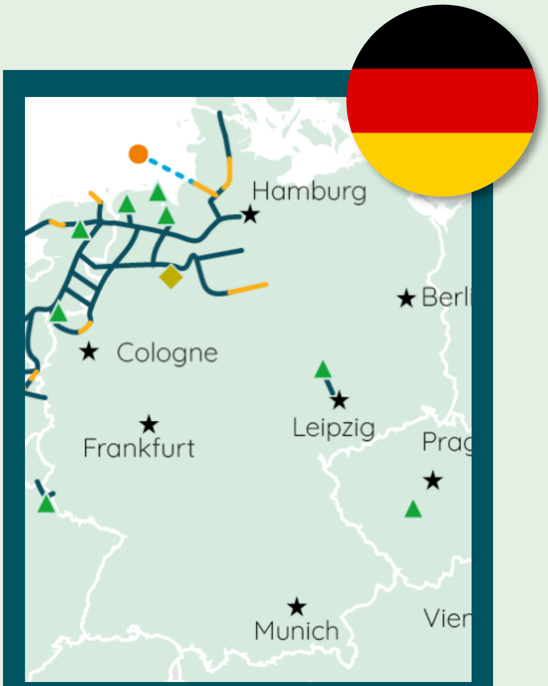
GRTgaz is developing the MosaHYc (Moselle Sarre HYdrogen Conversion) project, a cross-border project aiming to foster the development of a Hydrogen Valley at the heart of the Greater Region by converting existing pipelines to transport hydrogen. The project creates the first German-French hydrogen interconnection. MosaHYc is an essential link within a bigger "Grande Region Hydrogen" ecosystem. In addition, GRTgaz is leading Jupiter 1000, a power-to-gas project including electrolysis, injecting hydrogen into the existing gas grid (Teréga is one of the partners). The project is non-commercial and has been considered by the regulator to contribute to R&D activities and was granted with financial supports.

To refine their vision, GRTgaz and Teréga launched beginning of June a market consultation in France. The objective is to map more precisely the areas of production and of consumption. This process is a first step that will allow them to design the transport network to connect these locations in the long term.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure Both Teréga and GRTgaz indicate that the regulatory uncertainty and lack of framework combined with the unclear role of the gas TSO with regards to the transport of hydrogen is a barrier. This leads to difficulty to build a coherent economic vision and align stakeholders in the whole value chain (different hydrogen production costs, different levels of financial support across regions/countries, competition among project partners). Also, the lack of homogeneous regulatory provisions between EU member states is deemed a barrier. Given the current uncertainties, the French regulator is calling for more evidence on the demand and supply of hydrogen before considering the transport part. This shows the importance of visibility on the regulatory framework to allow investments in the relevant hydrogen infrastructure enabling market development.

Financing options in France In France, supply and demand for hydrogen are not developed yet. However, local interest around industrial clusters and ports is growing. To support the emergence of hydrogen clusters, both the French gas TSOs envisage a mixture of systems depending on local specificities (demand and supply). To support the development of these local hydrogen clusters and valleys in the beginning stages of the hydrogen backbone, a private system applying the same rules for all actors can be utilised. To trigger and ensure investments, commercial commitments with negotiated third-party access or grants (e.g. TEN-E or public fundings) are seen as an option. Ex-ante infrastructure planning should be considered to adequately size the pipelines. After 2030 when these clusters will gradually get interconnected by mainly repurposing existing gas infrastructure, regulatory rules should be revisited by the regulator to ensure non-discriminatory regulated third-party access. Temporary exemptions of the regulatory framework should be possible, depending on market conditions and on size of the actors. In the long run, the financing of the EHB will have to be a RAB based system.

4.4.4 Germany



Hydrogen backbone length in 2030
New: 210 km
Repurposed: 1,270 km

Germany could already have a hydrogen backbone of 1,500 km in 2030, consisting of approximately. 85% repurposed pipelines and approximately 15% new dedicated hydrogen pipelines. As part of the network development plan process (2020-2030), the German transmission system operators queried specific projects for the production or use of hydrogen. For 2030, the market participants asked for 1 GW of green hydrogen feed-in capacity, and 3 GW exit capacity. The German National Hydrogen Strategy calls for 5 GW of electrolyser capacity to be installed by 2030 and an additional 5 GW by 2035, based on an annual hydrogen demand of around 20 TWh for industrial purposes only. To close the gap in the entry-exit balance for hydrogen in 2030, the network operators envisage hydrogen imports from the Netherlands, the connection of salt cavern storage facilities, and additional feeds from wind farms equipped with electrolysers. It is expected that further requirements will become apparent in the coming years, in line with the German government's view of a 90-110 TWh hydrogen demand by 2030. The total hydrogen backbone in Germany between 2040 and 2050 is expected to be 5,900 km.

Political context Hydrogen is regarded as a political priority in Germany. The German Government has issued a National Hydrogen Strategy[12] for Germany in May 2020. Subsequently, the national regulator conducted a market consultation[13], assessing market participants' views on the need for a regulatory regime for hydrogen grids. Most market participants, including the German gas TSOs, regard the early implementation of a regulatory regime for hydrogen grids as a necessary pre-condition for the development of hydrogen infrastructures. Following this, the federal government launched a legislative process for the implementation of a regulatory regime for hydrogen grids in the German Energy Industry Act. The respective draft law was submitted to the federal parliament and it is expected to be passed in June 2021.

The draft law lays the foundation for a cost regulation of dedicated hydrogen pipelines. Detailed regulation will follow via an ordinance by the federal government. In addition, the Ministry for Economic Affairs and Energy intends to provide public funding under the European IPCEI regime to support first hydrogen infrastructures.

A joint cost recovery model for hydrogen and methane infrastructure within a single RAB is not yet foreseen in the current proposal. However, political support within the Bundestag, the federal parliament, is mounting for this approach. Parliamentary groups in the Bundestag plan to pass (along with the draft law) a motion calling for a joint cost recovery model. In addition, the German Ministry of Economic Affairs and Energy (BMWi) has signalled that they will advocate for an integrated regulatory framework for gas and hydrogen in the upcoming revision of the gas directive (2009/73) and gas regulation (715/2009) on a European level.

Ongoing projects OGE has launched alone and together with partners a number of initiatives and projects for the conversion of existing gas pipelines to hydrogen transport and the construction of new hydrogen pipelines. The two most advanced projects are "Reallabor Westküste 100" and "Get H2 Nukleus". For "Reallabor Westküste 100", a public funding was granted by the Ministry for Economic Affairs and Energy. For "Get H2 Nukleus", OGE has submitted an expression of interest for an IPCEI funding.

ONTRAS is currently pursuing several hydrogen projects which will connect hydrogen production and demand in Eastern Germany via dedicated hydrogen networks and link the region to the European Hydrogen Backbone. Projects include amongst others; the hydrogen hub "Doing hydrogen", a hydrogen ring around Leipzig "LHyVE" and the "Green Octopus" project, a 200 km hydrogen network (50% repurposed, 50% newly built) that connects an Energy Park with a hydrogen

[12] The strategy can be downloaded here: https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=4

[13] The results of this market consultation can be downloaded here: https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/NetzentwicklungUndSmartGrid/Wasserstoff/Konsultationsbericht.pdf?__blob=publicationFile&v=1

storage cavern and the industry valley of Salzgitter. All three projects have also been preselected by the German Ministry of Economic Affairds and Energy for the IPCEI process[14].

For each of these ONTRAS and OGE-projects, competitive hydrogen transport tariffs have been calculated. These tariffs are foreseen in a future mature hydrogen market with a larger number of consumers. However, during the initial phase of the market ramp up, public financial support, e.g. in the context of IPCEI, is necessary to bridge the initial funding gap. Otherwise the initially very small number of potential hydrogen consumers would be faced with high transport charges which would risk the development of the hydrogen market altogether.

Gasunie is developing a project HyPerlink, connecting national hydrogen producers, consumers and storage, and enabling import/export of hydrogen via cross border connections between Germany, the Netherlands and Denmark. Gasunie is also Lead Partner in the AquaDuctus project, which will transport up to one million tons of green hydrogen (from 2035) from the North Sea directly to the mainland. It is part of the AquaVentus initiative, which aims to build 10 gigawatts of electrolysis capacity for green hydrogen from offshore wind energy between Helgoland and the Doggerbank sandbank. Both Hyperlink and AquaDuctus have been shortlisted for IPCEI funding.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure The German government has drafted a hydrogen regulation that foresees a regulatory separation between gas and hydrogen networks. It has not yet clarified the provisions concerning the tariffs for hydrogen transport. This contributes to uncertainties on future revenues and the economic viability of investments and operation of hydrogen networks. One of the key issues to be solved is how the risk of prohibitively high tariffs can be mitigated. For example, a hydrogen network operator losing one of its initial two or three customers would have to raise tariffs for the remaining ones, even under a subsidy regime, which does not address this case.

Positive incentives are provided by government support schemes e.g. for regulatory sandboxes (Reallabore) and IPCEI projects. In order to foster and accelerate the development of a mature hydrogen market additional incentives are needed, among others rising CO_2 prices, a renewable gas target, technology neutral recognition of greenhouse gas emission reductions of hydrogen across all end-use sectors and applications, and measures such as contracts for difference that help to bridge the initial gap towards cost-competitiveness of hydrogen applications.

Financing options in Germany ONTRAS and OGE regard a joint cost recovery model for hydrogen and methane as the most appropriate solution to financing the ramp-up of hydrogen infrastructure in upcoming years. This would mean having a single network tariff for the hydrogen and the methane system based on the collective network costs of both systems, similar to the model currently applied to L- and H-gas networks in Germany. Such an approach would allow for natural gas consumers to contribute to the development of a hydrogen system, of which many of them will benefit in the future by having access to carbon-free energy when natural gas production is phased out. It would furthermore allow for lower transportation costs for early users of the hydrogen system thus supporting a quick transition and facilitating investments in hydrogen application. In the long run, methane consumers will benefit from such a model when natural gas demand declines and a decreasing number of consumers would otherwise have to bear the remaining costs of the methane system.

A separate cost recovery approach for hydrogen, as foreseen by the current revision of the Energy Act in Germany, could very well lead to prohibitively high network tariffs for early users of the hydrogen infrastructure given the small number of consumers at the beginning and the costs necessary for adapting infrastructure to hydrogen. It may therefore be a barrier to the realisation of a hydrogen market and could only be mitigated by decreasing the network costs for consumers with other schemes, such as subsidies and public support funds.

[14] BMWi IPCEI process project selection: https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210528-bmwi-und-bmvi-bringen-wasserstoff-grossprojekte-auf-den-weg.html

4.4.5 Greece

The hydrogen backbone in Greece will start developing before 2030 according to the recently submitted IPCEI "White Dragon" cluster project[15]. This project has recently been agreed upon, therefore it has not yet been included on the 2030 EHB map that was published in April 2021.

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 the installed capacity of Wind Power to 7 GW and Solar PV to almost 8 GW. This may lead to the need to use hydrogen in dispatchable power. The two main industrial clusters, in Thessaloniki and Athens, are potential large demand sources for hydrogen. Most of the hydrogen consumption is expected to come from industrial uses of pure hydrogen as feedstock product (e.g. refineries, chemical industries, etc.). The development of a dedicated hydrogen pipeline system, running in parallel to a section of the national gas transmission system, is envisaged.

Hydrogen backbone length in 2030

New:	670 km
Repurposed:	0 km

Political context Until today, no major discussion on the national hydrogen regulation has started in Greece. The development of the necessary regulatory framework for adaptation of the national natural gas transmission system to allow for blending of hydrogen, and the development of a dedicated hydrogen transmission system are considered important by policy makers. The future importance of hydrogen and hydrogen infrastructure is recognised.

Ongoing projects There are several gas infrastructure projects being developed in Greece. These projects indicatively include the expansion of the existing pipeline networks, the establishment of new compressor stations, development of new interconnections with adjacent systems and floating regasification facilities. New gas infrastructure projects are mainly financed via National Strategic Reference Framework (NSRF) funds, private loans and funding mechanisms from the TEN-E policy.

DESFA, the Greek gas TSO, is currently assessing the existing system to identify possible gaps and necessary measures for hydrogen injection and blending. Studies on the future hydrogen market development aim to identify and plan the future infrastructure. The financing of hydrogen projects, as part of the necessary expenditure will have to be covered through state aid (potentially NSRF or other funding program on a national level) and private loans, while the revenues will come through gas network tariffs for a certain period.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure DESFA considers the absence of a regulatory framework (either for blending or for pure hydrogen) and incentives for producers and consumers to be the main potential barriers to investing in, and developing hydrogen infrastructure in Greece. The lack of a dedicated funding mechanism and tools on a national level may prevent potential stakeholders from investing. Clear incentives for producers and consumers should be in place, as well as a clear regulatory framework, to accelerate the development of the hydrogen market in Greece. Potential incentives could be set from the regulator in the form of an increased allowed rate of return (WACC) for specific projects.

Financing options in Greece Suitable financing options for Greece are assumed by DESFA to be quite similar to those that are used for natural gas today. The national regulatory framework, which is expected to be developed, along with the revision of the EU's TEN-E policy, should provide a clear pathway to the available options for hydrogen infrastructure investments.

[15] 8 Billion Euro Greek Hydrogen Plan "White Dragon" Set For take-off (2021). https://fuelcellsworks.com/news/8-billion-euro-greek-hydrogen-plan-white-dragon-set-for-take-off/

4.4.6 Italy

Hydrogen backbone length in 2030
New: 530 km
Repurposed: 1,220 km

Italy could have a hydrogen backbone of 1750 km in 2030, consisting of 30% repurposed pipelines and 70% new dedicated hydrogen pipelines. The Italian backbone, by 2030, may stretch from Sicily to the hydrogen valley of Emilia Romagna. 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.

Political context Italian institutions have been active in the hydrogen discussion. The national regulator ARERA, assessed in 2020 options for experimenting with innovative network solutions, in relation to the integration of hydrogen into the networks. The Italian government has been among the first in Europe to issue a Hydrogen Strategy. The Preliminary Guidelines of the Italian Hydrogen Strategy were published in November 2020. The key targets for 2030 are: 5 GW of electrolyser installed capacity, up to €10 bn. of investments, up to 2% penetration of hydrogen in the final energy consumption, and up to 8 Mton CO2eq emissions avoided thanks to hydrogen. In addition, in the Italian RRP €18.2 billion are dedicated to renewable energies, hydrogen and sustainable mobility as a whole (€2 billion to hydrogen only). Moreover, the Italian Government is also involved in the development of an "Important Project of Common European Interest", IPCEI, looking at the hydrogen value strategic chain.

Ongoing projects Currently Snam has multiple ongoing initiatives on hydrogen infrastructure, three are worth noting: 1) Certification of the H_2-ready network, Snam and RINA, will assess and certify the compatibility of each natural gas pipeline of Snam's network to transport up to 100% hydrogen, and study and test the compatibility of industrial burners. Further experiments, analysis and technology scouting in various areas of hydrogen production, storage and distribution are planned. 2) the H2-NG fuel Compression station project aims to evaluate the feasibility and performances of existing compression stations when they are fed with H2NG. Several blends, with variable H2 molar percentage, are being tested employing a tailored injection system at various selected load levels measuring the performances of the investigated turbomachinery. 3) The H2-NG Separation membrane project aims to investigate the behaviour of separation systems, in order to assess the readiness to correctly supply sensitive end-users. The project assesses the separation solution of hydrogen from H2NG mixtures, using a pilot plant.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure In the view of Snam, for the hydrogen market to develop, both a stable regulatory framework and technical standards need be developed. With regards to the regulatory framework, it will need to determine the broader conditions for investment, including on how to finance the hydrogen infrastructure and provisions determining the role of the different players over the supply chain, notably that of gas TSOs. With to technical specifications: the technical specification UNI/TS 11537:2019 ("Introduction of biomethane into natural gas transport and distribution networks") sets a technical acceptability limit of 1% of hydrogen volume on biomethane that can be injected into the grid. However, there is no comprehensive technical standard for the large-scale injection of hydrogen into the natural gas transmission network.

Financing options in Italy It is Snam's expectation that a substantial part of the current gas demand will switch to hydrogen. In the run up to market development, Snam consider that public funding (national or EU) will be needed to reduce the potential impact hydrogen tariffs driven by the initially low hydrogen customer base.

4.4.7 The Netherlands

The Netherlands wants to develop a hydrogen backbone of 1,183 km in 2030, consisting of 85% repurposed pipelines and 15% new dedicated hydrogen pipelines. 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 first regions in the Netherlands where hydrogen transport infrastructure can be built are Rotterdam-Rijnmond (ready for operation in 2024) and the northern Netherlands (ready for operation in 2025). The province of Zeeland and the Amsterdam-IJmond region will follow after that. The national backbone can connect all five Dutch industrial clusters and link them to hydrogen storage locations and import- and export options by 2027. The backbone will be built out further to enhance interconnections by 2030. Gasunie is, together with TenneT and the Dutch Ministry of Economic Affairs and Climate Policy, are exploring the possibilities through a study called HyWay27, named for the year when the backbone is supposed to connect all industrial clusters.

Hydrogen backbone length in 2030
New: 202 km
Repurposed: 981 km

Political context Hydrogen infrastructure has been identified as a priority by Dutch policymakers. The Dutch Hydrogen Strategy (2020) underlines the government's desire to develop the market, stating a goal of 500 MW electrolysis capacity in 2024, and 3-4 GW in 2030. In the coming two years, a new Energy Act will be developed. Currently, there is no plan for hydrogen regulation on a legislative level, but rather the creation of the legal basis to assign a task and set basic rules for transport and storage infrastructure. The Dutch Ministry of Economic Affairs and Climate Policy will develop a hydrogen market design vision later this year and expects an independent system operator role for hydrogen. The ministry will look into the temporal and structural role of Gasunie for transport, storage, and conversion.

Ongoing projects In the Netherlands, 65 hydrogen IPCEI projects have been selected. Next to these projects, Gasunie has already repurposed a 12 km natural gas pipeline in Zeeland to transport hydrogen to Yara, a chemical company producing nitrogen fertiliser. Gasunie owns and operates a 1 MW electrolyser at the Zuidwending underground gas storage facility, converting 2,4 MW of solar PV into green hydrogen. Together with Nobian, Gasunie is working on plans to build a 20 MW electrolyser in Delfzijl.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure Barriers perceived by Gasunie are: 1. The upfront shortfall; a higher initial capacity than the volumes foreseen in the first years. 2. Uncertainty about initial volumes relative to capacity and final demand volumes, resulting in the possibility of a lack of income for the system operator. 3. No legal certainty on how asset transfer should occur, the price for selling these assets, and how this relates to the regulated asset value. An appropriate funding scheme is deemed necessary to manage these risks for the transmission operator. The Sustainable energy transition subsidy (SDE++) includes hydrogen production and could create opportunities to invest. However, market parties are not making use of this subsidy at the moment, as the subsidy is conditional on the running hours for electrolysers, which are too low to ensure a positive business case. The Ministry of Economic Affairs and Climate Policy is working on a subsidy instrument to stimulate the production of green hydrogen and the construction of electrolysers. The total available budget will likely be around €250 million and will be auctioned via a tender procedure.

Financing options in the Netherlands New infrastructure will be financed by Gasunie. However, most projects come with a serious potential funding gap. The uncertainty of this funding gap represents a big risk, which Gasunie would want to share with the EU and national government and with market parties. Gasunie does not see cross-subsidisation as a fitting option for the Netherlands. Together with the Dutch government, Gasunie is considering several options, and combinations of options, such as an upfront capital expenditure (CAPEX) subsidy, as well as a total expenditure (TOTEX) subsidy with an upfront guarantee for the maximum amount needed.

4.4.8 Spain

By 2030, Spain may have a hydrogen backbone of 1,520 km, mainly based on repurposed pipelines. Industrial clusters within reach of the proposed parallel network, therefore relevant for the initial development of the backbone, are along the Mediterranean coast and in the Center and North of the Peninsula. 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. By 2040 the complete Spanish hydrogen backbone would reach 6000 km.

Hydrogen backbone length in 2030
New: 0 km
Repurposed: 1,520 km

Political context During 2020-2021, the Hydrogen Roadmap, the Long-Term Decarbonization Strategy, and the Storage Strategy were published in Spain. In these documents, hydrogen plays a fundamental role in the decarbonization of difficult to decarbonise sectors and in energy storage. These documents form the starting point of the national discussion. However, there is no specific hydrogen regulation developed yet.

The Hydrogen Roadmap provides guidelines that aim to promote hydrogen supply and demand. Actual support mechanisms and incentives for production and demand, to facilitate the scale-up of hydrogen, remain still pending. The Hydrogen Roadmap contemplates national funding instruments aimed, fundamentally, at supporting initiatives and projects with high R&D content. The Spanish government has not yet explored the potential development of a hydrogen transmission network, as they perceive the timing as too soon to know whether and to what extent it will be required.

Ongoing projects Enagás, the Spanish gas-TSO, promotes hydrogen projects throughout the value chain, mainly linked to hydrogen production and blending with natural gas. Enagás has participated in the Re-stream study, aimed at studying the potential reuse of oil and gas infrastructure for hydrogen and CCS in Europe. The company is also engaged in H2GAR, an initiative on the assessment of H2 asset readiness, together with Fluxys, Gasunie, GRTgaz, National Grid, Open Grid Europe and Snam. This initiative was presented in the 34th Madrid forum held in October 2020.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure The main barrier, according to Enagás, is the cost of producing green hydrogen, which requires incentives and support mechanisms for the projects to be carried out. Furthermore, to establish the 2050 emission-neutral energy system political recognition of the need for a hydrogen backbone would be needed, the export-potential hydrogen produced in Spain should be considered, as well as the possibility of Spain becoming a transit country for hydrogen produced in North Africa. A coordinated planning of the energy system, allowing for optimizing investments, and taking advantage of the repurposing of the existing gas infrastructures would be needed.

Financing options in Spain According to Enagás, the current natural gas infrastructure RAB-based system seems suitable for the hydrogen backbone financing needs. A RAB-based system would make it possible to undertake the necessary investments (taking into account that the majority of the backbone (82%) would come from repurposing of the current network). Considering Enagás' core business is the development and operation of infrastructures under regulated conditions, they envisage a similar status for the hydrogen backbone.

Besides this, Enagás is closely following developments on sustainable finance, since the hydrogen infrastructure projects would generally be taxonomy-aligned and therefore eligible for EU funds, BEI financing and other green funding alternatives.

.

4.4.9 Sweden

Hydrogen backbone length in 2030
New: 1,040 km
Repurposed: 0 km

By 2030, Sweden can expect to see the development of hydrogen infrastructure from the north to the centre of the country, as well as an emergence of a more large-scale regional hydrogen infrastructure connecting the industrial demand centres in Lysekil-Stenungsund-Gothenburg, in the southwest of the country. Hydrogen infrastructure will connect the north-central part of the country – a region with an abundance of large-scale hydroelectric supply – with the steel & mining industry cluster further north in Norrbotten, as well as with smaller industry clusters in central Sweden (not on the map) – closer to Stockholm and other major cities. This North-Centre hydrogen corridor will consist exclusively of new hydrogen pipelines, and may stretch approximately 800 to 1,000km. From 2025 to 2030, as hydrogen demand materialises at both ends of this corridor, the development of hydrogen infrastructure is expected to begin with more regional networks, ultimately integrating into a larger hydrogen network. By 2030, a full national hydrogen backbone from south to north remains unlikely. However, from 2035 onwards, as hydrogen demand clusters expands into other industries and transport, and with the potential for Sweden to become a hydrogen exporter to mainland Europe – benefitting from lost-cost electricity supply from the north – a full national backbone may become a reality.

Political context The discussion on hydrogen is in the early stages in Sweden. The Swedish government has assigned the Swedish Energy Agency to present a National Hydrogen Strategy by November 2021.

Ongoing projects Most larger hydrogen infrastructure projects in Sweden are currently in the (pre-) feasibility phase. Opportunities are seen with (1) offshore wind (2) hydrogen production offshore (3) hydrogen transportation in pipelines to industrial demand centres and the chemical & petrochemical industries near Gothenburg (West-Coast). The transition of iron ore company LKAB related to the HYBRIT steelmaking technology is the most tangible initiative; it has a scale of 30-40 TWh hydrogen/year. Other projects are not public for now but may be disclosed by year end – the scale is 2-10 TWh across different locations in Sweden. The Swedish Gas for Climate TSO, Swedegas (part of Nordion Energi), is involved in discussions for a number of hydrogen projects. They intend to utilise a similar approach as in their core business (gas-TSO/DSO), needing long-term commitments from infrastructure clients.

Perceived opportunities and barriers to invest and develop hydrogen infrastructure Sweden only has a limited gas infrastructure today. Therefore, the future hydrogen network will require building new infrastructure. Potential barriers perceived by Nordion Energi are: (1) uncertainties related to future regulation (2) absence of a clear sector coupling strategy (3) no dedicated policy instruments for CO2 reduction (4) no liquid market or established trading mechanisms for hydrogen (5) our forecasts are based on learning curves for electrolysers that are currently still lacking a financing solution, and the forecast are also anticipating the solution of a number of barriers such as right of way/permits/sunk investments in old infrastructure etc.

Potential incentives for Nordion Energi: (1) Increasing CO_2 price and a broad commitment from the industry to "Go green". The actual incentives (current CO_2 price) are not sufficient to motivate this commitment, but the incentives seem to be based on anticipation of forthcoming incentives. Blue hydrogen is perceived by Nordion Energi as an important tool to start an early decarbonisation of the industry expecting it to become cost competitive prior green hydrogen solutions.

Financing options in Sweden Nordion Energi advocates a regulatory regime where the operation of a combined hydrogen and methane gas system is supported. This would enable the best overall system approach with coordinated inputs from biogas and low-carbon hydrogen, promoting a holistic transition from fossil fuels to renewables, building a financial bridge between the mature but stagnating natural gas market and the small but expanding hydrogen market and meanwhile facilitating cost savings by utilizing both existing and new infrastructure for the most efficient means.

Appendix A. Pipeline cost calculation

Table 2 summarises the throughput and cost assumptions used to estimate the investment costs associated with the European Hydrogen Backbone. Due to the developing market national cost assumptions might differentiate from the EHB assumptions.

Table 2: Pipeline throughput and cost assumptions

Parameter	100% Capacity	75% Capacity	25% Capacity
48-inch Pipeline Throughput [GW at LHV (TWh/y)]	16.9 (148)	12.7 (111)	4.2 (37)
36-inch Pipeline Throughput [GW at LHV (TWh/y)]	4.7 (42)	3.6 (32)	1.2 (10)
20-inch Pipeline Throughput [GW at LHV (TWh/y)]	1.2 (10)	0.9 (8)	0.3 (3)
New 48-inch Pipeline CAPEX (EUR/m)	2,750		
New 36-inch Pipeline CAPEX (EUR/m)	2,200		
New 20-inch Pipeline CAPEX (EUR/m)	1,510		
Repurposed 48-inch Pipeline CAPEX (EUR/m)	500		
Repurposed 36-inch Pipeline CAPEX (EUR/m)	400		
Repurposed 20-inch Pipeline CAPEX (EUR/m)	275		
Distance between compressors (km)	100-200		
Input pressure (bar)	30-40		
Output pressure (bar)	30		