Possible regulation of hydrogen networks

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ABBREVIATIONS

Acronyms & Abbreviations	
ACER	European Union Agency for the Cooperation of Energy Regulators
CAM NC	Capacity Allocation Mechanisms Network Code
CBA	Cost-Benefit Analysis
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization and Storage
CEER	Council of European Energy Regulators
CEM H2I	Clean Energy Ministerial Hydrogen initiative
CO2	Carbon dioxide
DSO	Distribution System Operator
EC	European Commission
EFET	European Federation of Energy Traders
ENTSOG	European Network of Transmission System Operators for Gas
ENTSOs	European Network of Transmission System Operators
EU	European Union
EUDP	Energy Technology Development and Demonstration Program
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
GEODE	The European association of energy local distributors
GIE	Gas Infrastructure Europe
GO	Guarantees of Origin
GTM	Gas Target Model
H2	Hydrogen
IPCEI	Important Project of Common European. Interest
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy

Acronyms & Abbreviations	
IRENA	International Renewable Energy Agency
LNG	Liquefied Natural Gas
MS	Member State
NDPs	National Development Plans
NRA	National Regulatory Authority
PCIs	Projects of Common Interest
PPPs	Public-Private Partnerships
PV	Photovoltaic
R&D	Research and Development
RED II	Renewable Energy Directive - Directive (EU) 2018/2001
TEN-E	Trans-European Networks for Energy
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UK	United Kingdom

1 Introduction

1.1 Objective & key outcomes

The EU is currently facing the challenges to fulfill the transition towards a greener global energy system at affordable cost and in line with the EU energy security of supply requirements. Currently, natural gas plays a pivotal role in the economy of the EU, accounting for approximately 23%[1] of the total primary energy supply in the EU27 and the UK in 2018, with growing share the last two years as gas gradually displaces coal in power generation. For the EU to achieve the targeted GHG emissions reduction of at least 55%[2] (legislative proposals to be presented by June 2021 to implement the new target) by 2030 compared to 1990 levels, renewable energy is required as well as a more integrated use of electricity and gas grids. Renewable and low carbon gases and gas infrastructure play an important role in achieving a net zero global energy system by 2050, in a secure and reliable way.

Studies have shown that clean hydrogen, i.e. produced from renewable sources (green) or decarbonized in other way (blue), can contribute to the decarbonization of the energy sector. Recently, the EC released its Hydrogen Strategy, outlining its vision to create a more efficient, integrated and optimized energy system, covering all different strands of action, from R&D to infrastructure, and its international implications. The new strategy aims to fully utilize the potential of clean hydrogen in order to assist the decarbonization process of the EU economy, whilst aligning with the 2050 climate neutrality goal, as specified in the European Green Deal.

Currently, in Europe there is a well-developed natural gas network of around 2.2 million km of pipelines[3]. At the same time, hydrogen currently accounts for ~1% of Europe's energy consumption[4] and it is mainly produced through carbon emitting processes with clean hydrogen amounting to only ~5% of the production. It is both desired and expected, however, that clean hydrogen will play a bigger part in the energy mix in the coming years, with a significant role in the decarbonization of multiple sectors across the economy, especially where reducing emissions is hard to achieve or not cost efficient. Meanwhile, industry leaders across the automotive, chemicals, oil and gas and heating sectors, consider hydrogen as a likely alternative to meet their sustainability objectives[5]. For many of the applications relevant to those sectors, technology has been proven and it is ready for use[6]. For instance, in transportation hydrogen-powered vehicles are commercially available or will become in the coming years in large cars, buses, trains, etc. In feedstock, large amounts of hydrogen are already used in refining, ammonia and methanol production, while large scale projects are already underway. For heat and power, already low concentrations of green or clean hydrogen could be initially blended into natural gas networks. Overall, the industry is prepared to invest, but there is a need for policy direction to support hydrogen's adoption and facilitate investments.

In view of the above, there is a need of assessing the energy transition aspects relevant to gas infrastructure, i.e., the regulatory, technical and economic aspects in support of achieving the EU's energy and climate policy objectives. This paper highlights the regulatory aspects of the accelerated refurbishment of existing gas infrastructure and the deployment of new ones for transport of hydrogen, in order to achieve the EU's energy and climate policy objectives.

Specifically, the paper focuses on the following key elements of the regulatory framework:

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[1] Source: Eurostat https://ec.europa.eu/eurostat/web/energy/data/energy-balances

[2] Source: European Commission https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1599

[3] Source: Gas and gas infrastructure – The Green Commitment. Recommendations for curbing climate change: biomethane, power to gas and gas as a fuel in transport. Green gas initiative. 2016

[4] Source: European Commission https://ec.europa.eu/energy/topics/energy-system-integration/hydrogen_en

[5] Source: Path to hydrogen competitiveness. A cost perspective. Hydrogen Council. January 20, 2020

[6] Source: Hydrogen scaling up. A sustainable pathway for the global energy transition. Hydrogen Council. November 2017

1. Regulatory recognition of infrastructure adaptation costs associated with handling of hydrogen through the existing gas infrastructure including transmission, storage and LNG terminal facilities
2. The time horizon of the regulatory period
3. Evaluation of infrastructure investments
4. Expected benefits from the implementation of the adaptations required to enable handling of hydrogen, and other significant aspects affecting the outcome of the benefits of the adaptation, with a focus on societal, economic and environmental benefits
5. Market, economic and financial terms and conditions to be accounted for by the regulators
6. New technologies and products, specifically those which address cross border barriers, their distribution by Member State and over time and the regulatory tools which could help achieve cross-border consistency and creating a single hydrogen market

The key outcome of the present paper is the identification of possible energy transition regulatory solutions to address the gasps and areas for improvement needed to allow the introduction of hydrogen to gas transmission, distribution, storage and regasification facilities.

1.2 Structure of the Background Paper

The present paper has been structured as follows:

Chapter 2. Gas grid infrastructure and hydrogen networks, provides the contextual background of the paper. It discusses the key features of natural gas infrastructure relevant to hydrogen injection and the grid configurations that can support the injection of hydrogen, either in the form of blends with methane or as pure hydrogen. The chapter concludes with an overview of case studies relevant to hydrogen injection into the grid. This section discusses projects currently in operation or under development, which illustrate potential approaches for the deployment of hydrogen network infrastructure.

Chapter 3. EU current Policy & Regulatory Framework relevant to hydrogen injection in the gas grid, provides an overview on the current EU framework applicable to the injection of hydrogen into the gas grid. This chapter contains a summary of EU Directives and Regulations, and Member State-specific practices, to obtain an understanding of how conducive the current framework is to hydrogen infrastructure development.

Chapter 4. Review and meta-synthesis, gathers a list of key recent papers and reports, EU-wide or Member State-specific, that answer key questions related to the regulatory aspects of hydrogen infrastructure development. This chapter also includes an analysis of the material according to the key regulatory aspects that need to be addressed for creating a conducive EU framework to hydrogen infrastructure investments.

Chapter 5. Hydrogen networks regulatory gap analysis, feeding from the results of the preceding chapters, presents the gap analysis and identification of areas that need to be addressed in the current regulatory framework and provides a summary of the key outcomes from our analysis.

2 Grid infrastructure and hydrogen networks

2.1 Key features of natural gas infrastructure relevant to hydrogen injection

The EU's energy sector is undergoing structural change, targeting areas ranging from sources of primary energy to energy transportation infrastructure, regulations and prices. Under the European Green Deal, the European Union Agency for the Cooperation of Energy Regulators (ACER), will contribute to Europe's decarbonization efforts. Regulation (EU) 2019/942, establishing ACER, and recasting Regulation (EC) 713/2009, grants additional competencies in ACER's role of coordinating the actions of national energy regulators, mostly in areas where fragmented national decisions of cross border relevance are likely to pose challenges for the internal energy market. Within this context, ACER's tasks should realize the objectives of the Regulation, the European Green Deal, as well as other EU-wide policies of relevance to energy transition. Significant cost effective decarbonization can occur through an integrated sectoral approach, using electricity, gas and to a lesser extent heat infrastructure. Besides improving energy efficiency to reduce energy consumption in the first place, the core of decarbonization lies in replacing fossil fuels with renewable sources of energy. Such energy transition will face many challenges, especially when it comes to storing large quantities of energy and transporting energy over long distances. Existing gas infrastructure has a lot to offer to overcome these challenges:

- allows to transfer energy over long distances at low cost and low energy losses;
- offers high cross-border energy transmission capacities;
- offers flexibility for meeting supply-demand balance. Pipeline linepack can be controlled by network operators, and contrary to electricity, supply and demand do not need to be totally balanced in real time.
- can provide large seasonal energy storage capacities;
- serves a large portion of the EU territory, and the fact that is for the most part not visible, helps acquire public acceptance.[7]

Furthermore, natural gas usage in Europe will decline, especially from 2030 onwards, thus pointing to subsequent reduction in utilization of gas infrastructure. Various other renewable and low carbon gases are expected to gradually replace carbon intensive natural gas, which justify the pursuit of the gas infrastructure in Europe. Amongst those, hydrogen has been identified as a decarbonization agent, provided it is produced with a low carbon footprint, either as green hydrogen (from renewables) or as blue hydrogen (from non-renewable energy sources). Further, hydrogen can be used either as an energy carrier, chemical feedstock or fuel, since it can support the large-scale integration of renewables, enable grid balance and seasonal storage and also reduce the carbon footprint of natural gas. Hydrogen could potentially represent a cost-effective decarbonization agent for emission intensive sectors, such as transport, heating, cooling and industries, especially where emissions reductions would be otherwise expensive or not practical. The integration of hydrogen into the gas grid, which covers varying geographies and scales, can facilitate the transition to decarbonization. Specifically, hydrogen can be:

- Injected in the form of an admixture into the natural gas grid (Currently, in the majority of the Member States, injection of H_2 in the gas transmission network is not applicable. Nevetheless, many of the NRAs report that a Hydrogen strategy is underway)[8];
- Used to produce synthetic methane for injection into the natural gas grid; or
- Injected directly into a dedicated hydrogen grid

[7] Source: Technical and economic conditions for injecting hydrogen into natural gas networks. GRTgaz. June 2019

[8] Source: ACER Report on NRAs Survey. Hydrogen, Biomethane and Related Network adaptations. July 10, 2020

In order to utilize the existing gas grids for hydrogen, three components of the gas chain need to be adapted, namely gas grids, storage facilities and end-use equipment. The following table depicts the required changes depending on the type of gas injected, either blended or pure hydrogen, specific to gas grids and storage facilities, which is the scope of our work:

Table 1. Infrastructure adaptations required to make the gas grids and storage facilities hydrogen-ready[9]

Hydrogen value chain component	Adaptations needed
Gas grids	Pipeline composition (polyethylene, steel, etc.), compressors, safety, admixture levels (hydrogen content) and metering stations
Storage facilities	Long-term seasonal storage of hydrogen in underground storages is technically feasible. Salt caverns are considered more suitable than underground storage in porous structures as UGS would have to be adapted if hydrogen in pure form or in blends is to be stored

2.2 Grid configurations suitable for hydrogen injection

The emergence of new gases, like hydrogen, poses challenges for the gas infrastructure in its present form, from a technical, economical and system-level standpoint. These challenges need to be addressed, in order to facilitate cross border trade and ultimately maintain a single European gas market. Key components of natural gas infrastructure include:

- The transmission pipelines, carrying gas from injection points to customers, through high pressure pipes
- The compression stations, powering gas through the transmission pipeline at adequate pressures.
- The valves, acting as gateways and enabling safe daily operations and maintenance works
- The metering stations, placed at transit and exit points to allow TSOs to monitor, manage and account for the gas in the pipes
- The city gate stations, reducing gas pressure levels and feeding gas through to end use systems through the distribution network[10]

Out of those, transmission pipelines account for most of the infrastructure and carry gas from production to industrial customers and distribution networks through high pressure steel pipes of large diameters. Depending on the supply potential and demand of hydrogen, biomethane and natural gas, grid functions will have to change, according to the Member State specific choice of technologies. This, in turn, will depend on a number of parameters, such as:

- Production potential of renewable gas
- Demand requirements
- Technical feasibility for hydrogen only, methane only and hydrogen – methane blends

[9] Sources: Hydrogen Europe Vision on the Role of Hydrogen and Gas infrastructure on the Road Toward a Climate Neutral Economy. A Contribution to the Transition of the Gas Market. April 2019
Technical and economic conditions for injecting hydrogen into natural gas networks. GRTGaz, et al. June 2019

[10] Source: European Hydrogen Backbone. How a dedicated hydrogen infrastructure can be created. Enagas, Energynet, Fluxys Belgium, Gasunie, GRTgaz, NET4GAS, OGE, ONTRAS, Snam, Swedegas, Terega. July 2020

- Status of sector coupling
- Energy mix, etc.

2.2.1 Blending hydrogen and methane

A likely configuration in the short to medium term, as per the EU Hydrogen Strategy, is one that can accommodate an increasing share of hydrogen in the grid, either as renewable hydrogen produced from electrolysis through renewable generated electricity, or as low carbon hydrogen from reforming of natural gas with Carbon Capture, Utilization, and Storage (CCUS) technologies. This configuration is based on acceptable thresholds of hydrogen and methane. Current research suggests that most applications, with the exception of industrial ones, using methane as raw material, could be adapted to work with hydrogen and methane blends with a 15-20% of hydrogen content, although adaptations needed to reach these targets can be quiet significant in terms of infrastructure and end user applications[11]. Beyond that threshold, any increase in hydrogen share would require infrastructure as well as end user appliances' adaptations or even replacement. Hence, any notion about the gradual increase of hydrogen concentration in existing gas networks, is considered up until a certain turning point, when a complete transition to dedicated hydrogen networks may prove to be more economical. Nevertheless, hydrogen injection into the gas grid is highly case specific, subject to the natural gas quality and local regulation[12].

2.2.2 Hydrogen only[13]

Under this configuration, hydrogen can be acquired through a range of sources and processes, e.g. from methane via pyrolysis, from renewable electricity via electrolysis or imported hydrogen, etc. Hydrogen has distinctly different characteristics from natural gas. And although blending hydrogen and methane can slightly change these characteristics, a pure hydrogen-ready grid, would translate into different technical considerations in each grid component. This holds true particularly with hydrogen in high concentrations and high pressures. Nevertheless, the effect of hydrogen on the pipeline material, is highly dependent on the type of steel and thus, it should be assessed on a case-by-case basis. Regarding hydrogen storage, this is technically feasible in underground storages (UGS) albeit the feasibility is also highly site-specific. In general, however, salt caverns are considered more suitable for this purpose.

[11] Source: ENTSOG 2050 Roadmap for gas grids. 2019

[12] Source: Hydrogen admission into existing natural gas infrastructure and end use. 33rd Madrid Forum – 23 & 24 October 2019. Marcogaz

[13] Sources: ENTSOG 2050 Roadmap for gas grids. 2019; European Hydrogen Backbone. How a dedicated hydrogen infrastructure can be created. Enagas, Energynet, Fluxys Belgium, Gasunie, GRTgaz, NET4GAS, OGE, ONTRAS, Snam, Swedegas, Terega. July 2020

3 EU existing Policy & Regulatory Framework relevant to the injection of hydrogen into the natural gas infrastructure

3.1 EU Directives and Regulations relevant to hydrogen and gas infrastructure;

The EU legislative framework is well established when it comes to natural gas and its infrastructure. At the heart of the EU framework for gas, lies the Third Gas Directive and its associated regulations. A number of the EU legal acts are also relevant to the deployment of hydrogen, either directly (e.g. renewable gas deployment including hydrogen) or indirectly (e.g. safety, environmental, transport law, etc.). Nevertheless, there are still fundamental legal and administrative barriers which might hinder the injection of hydrogen into the gas grid in the EU, with the main hurdle being the lack of a framework for grid injection requirements. Therefore, current legislation must be adapted and further developed to address the treatment of hydrogen and the injection of hydrogen into gas networks. Table 2, presents the key EU framework relevant to hydrogen and its infrastructure, followed by a summary of each legal act.

Table 2. EU Legal Acts relevant to the deployment of hydrogen in gas networks

Number	Title	Date
1.	Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II)	December 2018
2.	Directive 2009/73/EC concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC.	July 13, 2009
3.	DIRECTIVE (EU) 2019/692 amending Directive 2009/73/EC concerning common rules for the internal market in natural gas.	April 17, 2019
4.	REGULATION (EC) No 715/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on conditions for access to the natural gas transmission networks and repealing regulation EC 1775/2005.	July 13, 2009
5.	COMMISSION REGULATION (EU) 2015/703 establishing a network code on interoperability and data exchange rules.	April 13, 2015
6.	COMMISSION REGULATION (EU) 2017/460 establishing a network code on harmonized transmission tariff structures for gas.	March 16, 2017

Number	Title	Date
7.	Regulation (EC) No 942/2019 of the European Parliament and of the Council establishing an Agency for the Cooperation of Energy Regulators	13 July 2009
8.	COUNCIL REGULATION (EU) No 559/2014 establishing the Fuel Cells and Hydrogen 2 Joint Undertaking; - The Fuel Cells and Hydrogen Joint Undertaking (FCH JU)	May 6, 2014

The RED II Directive, sets new binding targets of at least 32% of EU final consumption by 2030 and addressed issues related to the integration of gas from renewable energy sources into the gas system. For instance, the Member States might extend the gas network infrastructure to accommodate and integrate gases from renewable energy sources. Nevertheless, it does not provide any clear definitions for renewable gases, hydrogen included.

Directive 2009/73/EC sets general rules for the transmission, distribution, supply and storage of natural gas and electricity, laying down the rules relating to the organisation and functioning of the natural gas sector, access to the market, the criteria and procedures applicable to the granting of authorisations for transmission, distribution, supply and storage of natural gas and the operation of systems. Article 1.2 of the Directive states that "*the rules established by this Directive for natural gas including LNG, shall also apply in a non-discriminatory way to biogas, gas from biomass or other types of gas in so far as such gases can technically and safely be injected into, and transported through the natural gas system*". Although the discussion on the safety and technical standards for hydrogen injection into the gas grid is currently ongoing, by virtue of Article 1.2 of the Directive, it can be considered that the Directive applies to blends of hydrogen and methane in the natural gas network in so far as the legal standard for the maximum allowed concentration of hydrogen is not exceeded.

Directive 2019/692/EC amends Directive 2009/73/EC concerning common rules for the internal market in natural gas. This amendment, however, refers to a new EC approach on the regulation of the gas transmission lines connecting Member States with third countries. Although this Directive is important for addressing barriers to the realization of the internal natural gas market, it does not address the need of fundamentally revising the Gas Directive to incorporate provisions for hydrogen.

Regulation (EC) 715/2009 sets non-discriminatory rules for access conditions to natural gas transmission systems and LNG facilities and storage facilities taking into account the special characteristics of national and regional markets.

Regulation (EC) 2015/703 establishes a network code which sets out rules regarding interoperability and data exchange as well as harmonized rules for the operation of gas transmission systems. It aligns the complex technical procedures used by transmission system operators within the EU, and possibly with transmission system operators within the EU and other neighbouring to the EU countries.

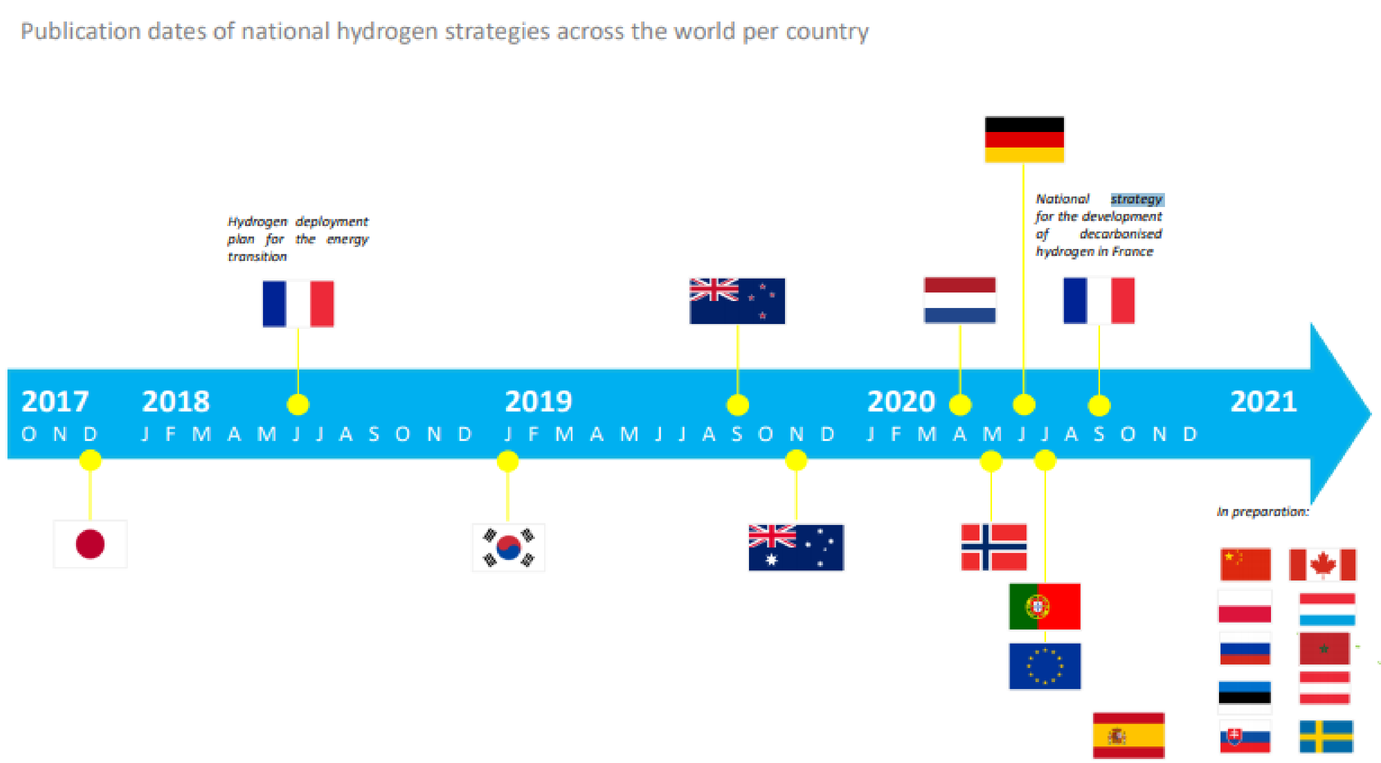
Regulation (EU) 2017/460 establishes a network code setting out the rules on harmonized transmission tariff structure for gas, including rules on the application of a reference price methodology, the associated consultation and publication requirements as well as the calculation of reserve prices for standard capacity products. This Regulation enhances tariff transparency and coherency (published revenues of TSOs). It does not make specific mention, however, to renewable gases or the tariff regulation proposed for them. Thus, as it stands, the regulation does not provide for the applicability of tariff methodologies to dedicated hydrogen networks and blended gas networks.

Regulation (EU) No 2019/942 establishes a European Union Agency for the Cooperation of Energy Regulators in order to assist the regulatory authorities in various regulatory tasks. Article 8, in particular, sets the Agency's "Tasks as regards terms and conditions for access to and operational security of cross border infrastructure", thus making ACER a stakeholder in regulatory issues relevant to hydrogen gas transmission and distribution.

Regulation (EU) No 559/2014 establishes the Fuel Cell Hydrogen 2 Joint Undertaking with the aim of increasing the effectiveness of hydrogen production from renewable energy sources and demonstrating use of hydrogen at large scale, to integrate renewable energy sources with the energy system.

3.2 Hydrogen national strategies in the EU

In line with the European outlook on hydrogen, albeit ahead of the Commission's release, the Netherlands and Germany published their national hydrogen strategies. These are further developed in the following sections. Portugal and most recently France also have released their hydrogen strategies, while Spain has launched its recently approved hydrogen roadmap. As of 2021, more EU countries are expected to publish their national strategies (Picture 1). For the purpose of this section we have included the German strategy, which presents the most ambition for the technology, and the Dutch, which has the most ambitious hydrogen infrastructure initiative.



Picture 1. Publication dates of national hydrogen strategies across the world per country. Source: Clean Hydrogen Monitor 2020. Hydrogen Europe, October 2020

3.2.1 The Dutch Hydrogen Strategy

The Dutch government has recognized that a solid regulatory framework is the key for the development of the hydrogen economy. In its "State Vision for the Development of Markets for the Energy Transition", dated on 22nd June 2020, the Minister of Economic Affairs and Climate Policy stated that the transition of the natural gas infrastructure to green gas and low carbon hydrogen is one of the main policy issues.

The Dutch gas market is regulated by the Dutch Authority for Consumers and Markets (ACM) and anyone engaging in gas supply, gas shipping or gas transportation, or participating in the operation of gas interconnectors or providing smart metering in respect of gas must have a license to do so under the Gas Act. Currently, the existing laws on regulation of gas apply in the context of hydrogen projects; however, no specific legislation has been adopted for hydrogen.

The injection of hydrogen is allowed into the gas grid (transmission & distribution), if the gas complies with the quality standards that are stated in the Gas Quality Decree. Physical blending of up to 2% is already achievable with minor adjustments and the government expects that this can be increased to approximately 10-20%. The Minister of Economic Affairs and Climate Policy recognized that more detailed studies are required, as it may be possible that the gas grid could handle 100% hydrogen. Terms and conditions regarding gas injection are included in a supplementary document of the Network Code, namely "Injection Code Gas TSO". Besides topics related quality, all the other rules related to the interaction among the producer and the network operator are the same as with the conventional natural gas, whereas gas from renewable energy sources is included in the "Definitions Code Gas".

On 30th March 2020, the Minister for Economy and Climate published a vision and action plan for hydrogen to 2050. Three phases are identified for hydrogen deployment. The first (current) phase involves the development of green hydrogen installations within industrial clusters where there is already demand for hydrogen. In a next stage it is likely for the development of a more extended network. In the long term, seasonal storage may be required potentially large-scale storage in salt caverns or empty gas fields.

The government recognizing its role in the development of the hydrogen infrastructure will review the conditions under which the existing gas grid could be used for the transport and distribution of hydrogen and the role of the network operators in the hydrogen chain. The national networks operators and network companies Gasunie and TenneT, as well as the regional network operators and network companies will be involved in this process. Connections with Germany and other neighboring countries and capacities required are also taken into consideration during the investigation. Laws and regulations for the deployment of the existing gas network is anticipated in the near-term.

The importance of support schemes aimed at research and demonstration projects, as well as the scaling-up and roll-out process is recognized:

1. Applied research and innovative pilot projects: The Energy Innovation Demonstration Scheme "DEI+" is supporting innovative pilot projects in the field of hydrogen. Within this scheme, a subsidy of 25%-45% of the eligible costs is provided with a ceiling of € 15 million per project depending on the company's size. Furthermore, the Mission-oriented Research, Development and Innovation Scheme is utilized to promote through tenders applied research and development of hydrogen's production.

2. Scaling up through new, temporary operating cost support: The Dutch government aims to facilitate the scaling-up process by making use of the existing Climate Budget funds available for temporary operating cost support as of 2021. By rearranging a part of the existing funds for hydrogen pilot projects within the DEI+ in an effort at reducing the cost for green hydrogen, about € 35 million per year are expected to be allocated for investments for the scaling-up process. This new allocation of existing funds is complementary to the DEI+, HER

(renewable energy subsidy module) and the SDE++ described below. Possibilities of state aid framework (e.g. IPCEI - Important Projects of European Common Interest -) are under examination.

3. Roll-out: The SDE++ scheme will support the hydrogen production by electrolysis for the first time from November 2020. Electrolysis production with 2000 full load hours is eligible for subsidy under this scheme, implying a subsidy intensity of 1064 €/ton CO2. However, the maximum subsidy under SDE++ amounts to 300 €/ton CO2. In addition, CO2 capture and storage for the production of blue hydrogen can compete in the CCS category of the scheme.

A system of Guarantees of Origin (GOs) is in place, while the possibility to increase the demand for green hydrogen (physical or via certificates) by introducing a compulsory blending obligation remains open to be addressed in a future policy.

3.2.2 Germany's National Hydrogen Strategy

Existing Hydrogen Injection Regulatory Framework

The German Energy Industry Act (Energiewirtschaftsgesetz) defines "biogas" in § 3, item 10c [14] referring collectively to several types of new gases including hydrogen generated by water electrolysis within the meaning of renewable energy sources reflected in the context of Directive 2009/28/EC (OJ L 140, 5 June 2009, p. 16). In this context, the Gas Network Access Ordinance (GasNZV, chapter 6) sets the regulatory framework enabling the "biogas" injection into the natural gas networks (transmission and distribution). Table 3 provides a summary of the main relevant provisions.

Table 3. Regulation for injection of hydrogen into the gas networks in Germany[15]

Main Topic	Provisions
Quality & Safety Requirements	• The producer has to ensure that the quality of the biogas injected at the entry point meeting the requirements of worksheets G 260 and G 262 of the German Technical and Scientific Association for Gas and Water (as of 2007) o However, there is also a possibility for a portion of the costs to be borne by the system operator • The network operator is responsible for the quality of delivered gas following the calibration requirements of worksheet G 685 of German Technical and Scientific Association for Gas and Water (as of 2007) • The network operator is responsible for odorization and the measurement of the gas quality
New Connections	• Network Connection Costs: o The network operator bears 75% of the costs o The connectee bears the remaining 25% of these costs, but for a network connection including a connection line of up to 1 km, a maximum amount of € 250,000 is determined o If the length of the connecting line exceeds 10 km, the connectee must bear the additional costs o The network connection is owned by the network operator o If additional connections are made within a period of 10 years after connected to the grid, the network operator must allocate the costs in such way the

[14] Sources: https://www.gesetze-im-internet.de/enwg_2005/__3.html; https://energyblawg.files.wordpress.com/2018/12/181213_Energiewirtschaftsgesetz_Energy-Industry-Act_teaser-1.pdf

[15] Source: http://www.gesetze-im-internet.de/gasnzv_2010/BJNR126110010.html#F774449_02

Main Topic	Provisions
	connection was implemented at the same time as described above and reimburse the connectees for any additional amount paid o If the system's commissioning date provided in the implementation timetable is exceeded due to network operator's reasons, all costs are borne by the operator. If the connectee has already made advance payments, the network operator must reimburse them • Network availability and maintenance: o The availability of the network connection must be ensured by the network operator on a permanent basis (at least at 96%) o The network operator is responsible for the maintenance and operation of the network connection bearing this cost o If deemed appropriate, the network operator must allow the access of the connectee or his agent to the rooms for the inspection of the technical equipment and the measuring equipment • Additionally services: o The connectee and the network operator can contractually agree further rights, obligations, services, and share mutually the additional costs • Network Connection Procedure for a new connection: o Within 2 weeks after the receipt of the connection's application of the connectee applicant, the network operator must inform him on the tests and studies needed to be carried out in order the operator to make the decision on the connection o If additional information is required, the network operator must request this from the applicant within 1 week of the receipt of the application. The period of 2 weeks specified in the previous point begins after the receipt of the complete information by the network operator o If necessary, other network operators are obliged to participate in the examination for the determination of the connection requirements o The connectee can request from the network operator(s) to carry out the tests based on his assumptions. o The connectee must be informed of the results of the tests immediately, but no later than 3 months after receipt of the advance payment o The connectee bears the necessary costs of the tests and the studies • Guaranteed minimum entry capacity: o A minimum guaranteed feed-in capacity is ensured for the producer by the network operator • Construction implementation & Estimated time for a new connection: o The construction of the facility needs to begin within 18 months after the commitment of the producer to a minimum capacity excluding any delays which cannot be controlled by the connectee o The construction implementation's schedule is agreed among the producer and the network operator including milestones for example for the land acquisition, permit acquisition, approval of grid connection work by connectee, placing orders for equipment, actual construction, commissioning date o The implementation schedule is submitted to the regulatory authority by the network operator o The network operator has the obligation of disclosing all the costs for planning and construction to the connectee o The efficiency of the network operator must always be preserved according to the Network Code

Main Topic	Provisions

Network Access	• Priority of access:
	  o Network operators are obliged to conclude entry contracts and exit contracts primarily with shippers of biogas and to transport biogas as a priority, provided that these gases are network- compatible
	• Refusal rights for receiving biogas:
	  o Network operators can refuse to feed in biogas if this is technically impossible or economically unreasonable
	  o The feed-in cannot be refused with the indication that there are capacity bottlenecks in a network directly or indirectly connected to the connection point, provided that the network's technical-physical capacity is given
	  o If the network operator rejects an application for connection, he has to prove the existence of the reasons according to § 17 paragraph 2 of the Energy Industry Act
	  o If the connection to the desired connection point is refused, the network operator must at the same time propose to the connectee another connection point that realizes the expressed intentions of the connectee in the best possible way.

Balancing	• Biogas balancing requirements:
	  o Market area managers are obliged to offer expanded balancing for the entry and exit of biogas through the offer of extended balancing group contracts
	  o Special biogas balancing group contracts include balance adjustment of 12 months – balancing period (or less if initially agreed among biogas balancing group's manager and the market area manager) and a flexibility framework of ± 25%
	  o Positive final balances from a previous period can be transferred to the following balancing period if the biogas balancing group continues its operation over a subsequent balancing period or in other case, differences exceeding the flexibility must be compensated according to a transparent and non-discriminatory procedure
	  o On the other hand, the biogas balancing group manager pays the market area manager a fee of € 0.001 per kWh for the use of the flexibility framework actually utilized, whereas the service is monitored by BNetza within the lines of §35, par. 1(7) of the Energy Industry Act
	• Transfer of quantities between balancing groups:
	  o Transfer of quantities from biogas balancing groups to natural gas balancing groups is possible,
	  o No transfer of quantities from natural gas balancing groups to biogas balancing groups is allowed
	• Information exchange:
	  o Before the start of each balancing period, the balancing group manager informs the market area manager about the expected entry and exit quantities and their scheduled distribution for the balancing period

Network planning	• Availability of annual network capacity: o The network operator must implement all the economically reasonable measures to increase the capacity in the network in order to guarantee the annual feed-in and the ability of satisfying the demand for transport capacities for biogas • Promotion of investments for feed-in of biogas to upstream networks:

Main Topic	Provisions
	○ The network operator must ensure the ability of feed-in of biogas back into the upstream networks (e.g. to transmission network if biogas injected at distribution level) including the installation of any necessary additional facilities such as for de-odourising and drying of the biogas ○ The network operator has to check to what extent the feed-in of biogas can be realized with no or reduced admixture of liquefied gas taking into account the future biogas feed-in
Transparency	• Report on amount of gas injected to the networks: ○ The network operator should immediately report the feed-in quantities in energy units that received to the connectees, the balancing group and the third parties determined by the connectee

German Hydrogen Strategy

The Federal Government of Germany approved the "National Hydrogen Strategy" on 10th June 2020[16]. This Strategy aims at the enhancement of the domestic hydrogen's production and its utilization principally in the industrial and mobility sectors while keeping in mind the heating sector. An amount of about €7 billion earmarked for speeding up the market rollout of green hydrogen technology in Germany and additionally another €2 billion will be harnessed for fostering international partnerships with other countries.

Among the various needs and goals determined, the injection of hydrogen into the transmission gas grids is also included though:

- the enhancement of gas transport infrastructure including the revision and the development of the regulatory framework and the technical requirements for the gas infrastructure, the examination of the compatibility of existing gas infrastructure, the needs for upgraded gas infrastructure and/or the development of new dedicated hydrogen networks,
- building up and securing the quality assurance infrastructure for hydrogen transport and storage though the development of scientifically accepted and regulated measurement methods and assessment criteria, and internationally accepted standards and technical and safety standards, and
- paving the way for imports and cooperation with other EU-MS.

The German government has developed an action plan enumerating a total of 38 measures that will take place in the first phase of the Strategy including the market ramp-up and the well-functioning of the domestic market by 2023. Issues such as research and development and international aspects are going to be tackled as well. The next phase, which is due to begin in 2024, is about stabilizing the newly emerging domestic market taking into consideration the European and international dimensions. It is noted that a secure, reliable and needs-based hydrogen supply and the long-term transformation process could be implemented via drawing on the potential of existing infrastructure as needed, and initiating the construction of new elements if necessary, implying that the investigation into the following elements should start immediately:

1. the possibilities for using existing structures (dedicated hydrogen infrastructure & parts of the natural gas infrastructure that can be adjusted and backfitted to allow hydrogen injection), as well as
2. the possibilities to re-dedicate and re-use pipelines etc. for future hydrogen supply.

The aforementioned actions require the preparation and the development of the essential regulatory basis for the construction and the expansion of the hydrogen infrastructure expected to be ready in the near term.

[16] The National Hydrogen Strategy, the Federal Ministry for Economic Affairs and Energy, 10th June 2020 (https://www.bmbf.de/files/bmwi_Nationale%20Wasserstoffstrategie_Eng_s01.pdf)

Additionally, efforts will be made for the better linking up of the electricity, heat and gas infrastructure considering the potential of the existing hydrogen infrastructure and ensuring its compatibility in the EU context.

4 Review and meta-analysis of material related to the injection of hydrogen into the grid

A review has been carried out to identify all material whose primary focus is the regulatory aspects of hydrogen networks in the EU. Particular care was taken in selecting material that reflects current progress (topicality - focusing on material dated between 2017-2020), and whose lead organization is an official EU organization or other top-tiered institution/organization. At this point, it is worth mentioning that the emergence of a clean hydrogen regulatory framework is still in its infancy. As such, the relevant material listed reflects the need for a conducive hydrogen framework, but it is still broad in scope and of variable content. Thereby, for the purpose of our analysis, we look into key regulatory aspects, often addressed from different perspectives in each paper, and we provide an overview of the key considerations that need to be accounted for in the future for the injection of hydrogen into the grid.

It is noted that the hydrogen sector is a rapidly evolving part of the energy sector, affected by new trends and energy market evolvements. The selected material has been collected and assessed, taking into account that some of them are continuously being updated. However, the Consultant is continuously evaluating the new trends and updated reports and proceeding to data update for the finalization of this background paper, if deemed necessary.

4.1 Methodology

The following database contains publications, reports, proceedings and other papers of major organizations and institutions pertinent to the regulation of hydrogen networks. The initial screening of the material focused on identifying topical reports, papers and other relevant material. The list was cross-checked and enriched by key stakeholders during consultation sessions. We then shortlisted the papers, by considering material that focuses on networks at transmission systems operators' level. The shortlisted material was examined in terms of the information it contains, considering certain assessment areas. The material used was further shortlisted to include papers that contained regulatory implications on at least two of the assessment areas. The resulting core list consists of 21 papers and it is presented in Table 4. The assessment areas are illustrated in Table 5.

Table 4. List of material used for the purpose of systematic analysis

Report No	Title	Country/Region	Lead organization	Publication year
1.	The Bridge Beyond 2025 Consultation Paper	EU-wide	ACER & CEER	November 19, 2019
2.	ACER report on Hydrogen, Biomethane and Related Network Adaptations	EU-wide	ACER	July 10, 2020
3.	EFET comments on the Roadmap for an EU Hydrogen Strategy	EU-wide	EFET	June 11, 2020

Report No	Title	Country/Region	Lead organization	Publication year
4.	A hydrogen strategy for a climate neutral Europe	EU-wide	EC	July 8, 2020
5.	Hydrogen generation in Europe: Overview of costs and key benefits	EU-wide	EC/Guidehouse & Tractebel Impact	July 27, 2020
6.	Questions and answers: A Hydrogen Strategy for a climate neutral Europe	EU-wide	EC	July 8, 2020
7.	ENTSOG 2050 Roadmap for Gas Grids	EU-wide	ENTSO-G	2019
8.	European Hydrogen Backbone - How a dedicated Hydrogen infrastructure can be created	EU-wide	Enagás, Energinet, Fluxys Belgium, Gasunie, GRTgaz, NET4GAS, OGE, ONTRAS, Teréga, Snam and Swedegas	July 17, 2020
9.	Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure	EU-wide	Directorate – General for Energy (EC)	April 30, 2020
10.	Hydrogen from renewable power - Technology outlook for the energy transition	Global	IRENA	September 2018
11.	Evaluation of Responses - Stakeholder Comments on CEER's Public Consultation on Regulatory Challenges for a Sustainable Gas Sector	EU-wide	CEER	November 19, 2019
12.	Regulatory Challenges for a Sustainable Gas Sector Public Consultation Paper	EU-wide	CEER	March 22, 2019
13.	The future of gas networks -key issues on debate		The Oxford Institute for Energy Studies	

Report No	Title	Country/Region	Lead organization	Publication year
14.	Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy - A contribution to the transition of the gas market	EU-wide	Hydrogen Europe	April, 2019
15.	Technical and economic conditions for injecting hydrogen into natural gas networks	Global	GRTgaz, GRDF, Geomethane, Elengy, Terega, Storengy, REGAZ, R-GDS	June, 2019
16.	Towards the New Age of Gas Networks - Proposal on the Regulation of a European Hydrogen Infrastructure	EU-wide	GEODE	May, 2020
17.	Gas goes green - Delivering the pathway to net zero	UK	Ena (energy networks association)	March 2020
18.	The European gas infrastructure can help deliver the EU hydrogen strategy - Innovative projects under the umbrella of Gas Infrastructure Europe	Europe-wide	GIE	July 8, 2020
19.	Hydrogen 2030: The blueprint	EU-wide	Hydrogen Europe	May, 2020
20.	Netherlands: Government Strategy on Hydrogen	Netherlands	Dutch Government	April 6, 2020
21.	Germany: The National Hydrogen Strategy	Germany	Federal Ministry for Economic Affairs and Energy	June 10, 2020

The review sought to identify material related to the regulatory aspects of the accelerated refurbishment of the existing energy infrastructure and the development of new ones, relevant to hydrogen injection. The collected material differs in scope, yet focus was placed on the following assessment areas.

Table 5. Key assessment areas and respective considerations

Assessment Area	Key Assessment Considerations
The acknowledgement of infrastructure adaptation costs incurred by the network operators and gas facilities, specifically with respect to transmission, storage and liquefied gas facilities	• Infrastructure governance (responsibility and planning network infrastructure)
	• Provisions for infrastructure investments and adaptations
	• Incentives and support for innovation to TSOs
The time horizon of the regulatory period	• Identification of the priority levels
	• Timeframes and objectives
	• Sandbox frameworks and trial periods
	• Strategies, policies, etc.
Evaluation of infrastructure investments	• Cost-Benefit-Analysis
	• Other investment appraisal approaches
The benefits expected from the adaptations in developing a hydrogen network	Sector integration benefits;
	• System flexibility and security of supply
	• Environmental benefits
	• Job creation and other socio-economic benefits
Market, economic and financial terms and conditions to be accounted by regulators for hydrogen	• Barriers to market entry
	• Enablers of market entry
New technologies and products with a focus on those who address cross border barriers, for hydrogen handling	• Guarantees of origin for hydrogen and other green certificates
	• Other solutions that are compatible with cross-border trade (gas quality inventories etc.)
	• R&D and other projects of cross-border relevance

The regulatory aspects covered, consider the interplay between technological innovations, infrastructural needs and market prospects, hence why they represent the backbone of our analysis. For the scope of this work, we first determined the degree to which each of the assessment areas was addressed across the list of papers.

Table 6 illustrates the frequency these areas were encountered across the reports examined so far:

Table 6. Frequency of assessment areas addressed in the shortlisted material

Assessment Area	Addressed	Not addressed
The acknowledgement of infrastructure adaptation costs incurred by the network operators and gas facilities, specifically with respect to transmission, storage and liquefied gas facilities	16	5
The time horizon of the regulatory period	14	7
The benefits expected from the adaptations in developing a hydrogen network:		
a) Evaluation of the financial return on infrastructure investments	6	15
b) Other benefits expected from the adaptations in developing a hydrogen network	8	13
Market, economic and financial terms and conditions to be accounted by regulators for hydrogen	12	9
New technologies and products with a focus on those who address cross border barriers, for hydrogen handling	14	7

In the following sections, we perform a review of the listed material, discussing each assessment area individually. The analysis contains the relevant key information which is either directly or indirectly addressed in each paper.

4.2 Acknowledgement of infrastructure adaptation costs

In the material included in our analysis, the acknowledgement of infrastructure adaptation costs is being fairly represented, although there is variation in the way it is addressed. Amongst the material reviewed, 16 out of 21 papers address the issue. Table 7 summarizes the relevant key considerations discussed in each paper.

Table 7. Key aspects covered with respect to the acknowledgement of infrastructure adaptation costs

Material	Key regulatory aspects covered
A Hydrogen Strategy for a climate neutral Europe	Infrastructure governance (responsibility and planning of network infrastructure): • Infrastructure planning on the basis of ten-year network development plan (TYNDP) for financing and operating specific to network operators • Review of regulatory framework to allow financing and operation in a competitive decarbonized market
	Provisions for infrastructure investments and adaptations: • Investments of some 65 billion euros from now to 2030 for hydrogen transport, distribution and storage, and hydrogen refueling stations
	Incentives and support for innovation to TSOs: • European Clean Hydrogen Alliance, to facilitate and implement the actions of the EU Strategy and scale-up investments • Instruments deployed to promote private investments, PPPs and pilot lines
The Bridge beyond 2025	Infrastructure governance (responsibility and planning of network infrastructure): • Change in governance arrangements especially concerning the legislation in relation to the TYNDP
	Provisions for infrastructure investments and adaptations: • NRAs should recognize the costs for further introduction of tradeable permits or taxes on emissions
NRA Survey on Hydrogen, Biomethane and related network adaptations	Provisions for infrastructure investments and adaptations: • MS NRAs are being aware of adaptations and/or investment projects related to H2 blending. No specific provisions in most NDPs
	Incentives and support for innovation to TSOs: • MS NRAs report there are currently no specific incentives
The 2050 Roadmap for gas grids	Provisions for infrastructure investments and adaptations: • NRAs would be asked to take into account the investment and adaptation costs on the condition of proper consultation to ensure efficiency, in terms of the the development of pilot projects
	Incentives and support for innovation to TSOs: • Refurbishing parts of existing infrastructure for 100% hydrogen or construction of new ones may require support schemes (e.g. PCIs) • Regulatory support for R&D and European funding • Legal framework to allow TSOs to transport CO_2 in addition to natural gas
Hydrogen generation in Europe: Overview of costs and key benefits	Provisions for infrastructure investments and adaptations: • Techno-economic perspective: costs associated with the refurbishment of existing natural gas pipelines and developing new dedicated H2 infrastructure
European Hydrogen Backbone	Provisions for infrastructure investments and adaptations: • Techno-economic perspective: Costs associated with creating a hydrogen grid
The Public Consultation on	Infrastructure governance (responsibility and planning of network infrastructure):

Material	Key regulatory aspects covered
Regulatory challenges for a sustainable gas sector	• Regulation with a focus on planning in the context of a TYNDP plan, with NRAs and ACER being responsible for assessing and/or approving the TYNDP
Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy	Incentives and support for innovation to TSOs: • Clear, predictable and non-discriminatory policy framework to support the roll-out of activities/investments
Hydrogen 2030: The Blueprint	Provisions for infrastructure investments and adaptations: • Techno-economic aspects of creating a backbone Incentives and support for innovation to TSOs: • Grants/subsidies and subordinated loans in support of pipelines' investments and/or adaptations
EU Commission Questions and Answers on the Hydrogen Strategy for a climate neutral Europe	Incentives and support for innovation to TSOs: • Launch of the European Clean Hydrogen Alliance and the instruments to be used for investing in hydrogen
Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure	Infrastructure governance (responsibility and planning of network infrastructure): • Future-proof planning of gas infrastructure • Integrated planning of infrastructure between TSOs and DSOs and across sectors (electricity and gas) • Might be appropriate to extend the role of TSOs and DSOs to be allowed to develop and operate hydrogen networks under the same regulatory framework as natural gas networks Provisions for infrastructure investments and adaptations: • Authorities to improve the transparency and the vision of future infrastructure constraints and costs of the energy system Incentives and support for innovation to TSOs: • TEN-E and CEF regulations to support projects facilitating the integration of renewable gases and the connection of renewable gases production to the grid
Technical and Economic conditions for injecting hydrogen into natural gas networks	Provisions for infrastructure investments and adaptations: • Operators to coordinate and share R&D efforts for all technical injection routes identified (different hydrogen injection thresholds) • R&D investments to be integrated into the expenditure covered by the tariffs Incentives and support for innovation to TSOs: • EU funding for joint R&D actions

Material	Key regulatory aspects covered
The Gas Goes Green Initiative: Delivering the pathway to net zero report	Infrastructure governance (responsibility and planning of network infrastructure): • Joint infrastructure planning for gas infrastructure needs (network operators-producers-suppliers)
The European Gas Infrastructure can help deliver the EU Hydrogen Strategy (GIE)	Infrastructure governance (responsibility and planning of network infrastructure): • Enable network owners to operate several categories of gases, including hydrogen through amendments of relevant EU legislation (e.g. TEN-E regulation)
	Incentives and support for innovation to TSOs: • Provide network operators with incentives to adapt their infrastructures to cope with the coexistence of different gases
Dutch Government Strategy on Hydrogen	Infrastructure governance (responsibility and planning of network infrastructure): • Government cooperation with network operators and network companies to assess the potential of using the existing gas grid for hydrogen
	Provisions for infrastructure investments and adaptations: • Creation of a North-Western Europe hydrogen hub in the Netherlands
Germany's National Hydrogen Staretgy	Infrastructure governance (responsibility and planning of network infrastructure): • Action Plan for laying the regulatory basis for the construction and expansion of hydrogen networks

Hydrogen Strategy for a climate neutral Europe foresees investments of some 65 billion euros from now to 2030 for hydrogen transport, distribution and storage, as well as for hydrogen refueling stations. It recognizes that since existing natural gas pipelines are owned by network operators, often not allowed to own, operate and finance hydrogen pipelines, a review of the regulatory framework is in order to allow financing and operation in a competitive decarbonized market. It also refers to the support of these investments, for which the Commission has established the European Clean Hydrogen Alliance, to facilitate and implement the actions of the EU Hydrogen Strategy and scale-up investments across the hydrogen value chain. The Alliance will also facilitate cooperation in a range of large investment projects, including Important Projects of Common European Interest (IPCEI). Furthermore, the Strategy explicitly mentions the need for support from European funding pots, such as the InvestEU programme, part of the new recovery instrument Next Generation EU, which has doubled its budget to help kick-start the hydrogen economy. Other sources of funding referred to, are the European Regional Development Fund, the Cohesion Fund, which will benefit from a top-up in the context of the new initiative REACT-EU, and the Just Transition Fund, which is set up to help fossil-fuel dependent regions to transition to clean energy. For financing and operating specific to the network operators, as mentioned, there will need to be infrastructure planning as on the basis of ten-year network development plan (TYNDP), to serve as a means of incentivizing investments.

The Bridge beyond 2025, recognizes the responsibility of TSOs at national level for planning network infrastructure and the determination of remuneration for investments by NRAs. It highlights the governance arrangements needed, including changes to the legislation in relation to the TYNDP, amongst others. The report underpins the need for analysis to test how robust each infrastructure investment is under different scenarios, as well as the need for ACER to set binding guidelines, as opposed to currently expressing non-binding opinions for the TYNDP development. Another important aspect covered in this report, is the obligation of TSOs, storage operators and

LNG operators above a size threshold, to measure and report their methane emissions according to a standard methodology, followed by an action plan at operator level to address such emissions. As suggested, the NRAs should recognize these costs for further introduction of tradeable permits or taxes on emissions.

The ACER report on Hydrogen, Biomethane and related network adaptations aims to spark regulatory discussions, particularly on network adaptations and investments needed at TSO level, with a focus on technical issues rather than on regulatory policy options. The survey mentions that more than half of the respondents (57%, 13 replies), are aware of H2 adaptations and investments blending projects in order to accept or increase H2 acceptance in gas transmission, yet National Development Plans (NDPs) do not foresee such investments, with the exception of Belgium, France and Slovenia. Furthermore, most NRAs report that there are currently no specific incentives for TSOs to develop projects for H_2 injection in the gas grid. This is also expected, since for networks accommodating blends of hydrogen and methane, the blending limits need to be decided first. The Report also makes a distinct mention to dedicated hydrogen networks, where about 19 respondents, reported that there are currently no plans for such networks in the foreseeable future, while the member states that already have set plans, like Germany, France, etc. have not determined yet whether those will be operated by regulated TSOs.

In ENTSOG's *2050 Roadmap for gas grids*, regulatory challenges are discussed, including the encouragement of initially R&D and pilot projects by the TSOs, amongst others, to test and roll out new technologies, with the NRAs being asked to acknowledge and take into account the related costs of infrastructure investments for the controlled development of pilot projects, as necessary for decarbonization, provided that appropriate stakeholder consultation takes place to ensure the efficiency of such investments. The Roadmap also underpins the support and regulation needed to incentivize investments. It is specifically noted that in the case of using blends of hydrogen and methane, the TSOs are foreseen to invest in conversion facilities either in competition with commercial investors or in non-commercial business cases, where TSOs invest in a regulated framework (for instance, under the framework of a regulatory sandbox). When examining the dedicated hydrogen pathway, the Roadmap recognizes the optimization of infrastructure as a result of coordinated planning reflecting the development needs of the sector (full/partial conversion of existing pipelines, etc.). ENTSOG also finds that sustainable approach to decarbonization will include CCUS, and thus, besides storage, CO2 transportation will be needed as well. The paper recommends that legislation should be amended, including the 2009/73/EC Directive to allow TSOs to be able to transport also CO_2.

The report on *Hydrogen generation in Europe: Overview of costs and key benefits*, mentions the costs of amongst others, the H_2 transmission networks, both in terms of refurbishment of existing natural gas pipelines and in terms of new dedicated H_2 infrastructure, nevertheless, it does not cover the acknowledgement of adaptation costs by the operators from a regulatory standpoint per se.

The same holds true for the *European Hydrogen Backbone*, which concludes on the cost of creating a backbone allowing for hydrogen to be transported cost-effectively across long distances in Europe. This paper also poses implications on policy making for sustainable finance and the review of gas legislation for enabling a competitive decarbonized market. Nevertheless, in essence, it focuses on the initial techno-economic aspects of creating a hydrogen grid, but does not account for long-term transmission arrangements or for the regulatory aspects of investment costs needed by the TSOs in future.

The *Public Consultation on Regulatory challenges for a sustainable gas sector*, covers the infrastructure investments and regulation with a focus on planning in the context of a TYNDP plan, with NRAs and ACER potentially being responsible for assessing and/or approving the TYNDP, the scenarios included as well as the Cost Benefit Analysis (CBA) methodology, to avoid promotion of the TSOs' interests alone.

In *Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy*, it is noted that specifically in terms of power to gas infrastructure, a tendering process should be launched to allow for all players to invest through support mechanisms. Yet, should that not be feasible, TSOs shall be able to directly invest as a regulated activity, until the market conditions become mature enough to launch tenders. In the case of investments by TSOs, adequate regulatory oversight should be in place, to ensure transparent access to the service.

Hydrogen 2030: The Blueprint refers to the investment needed in, amongst others, transport and storage infrastructure. Although it does not include any mention of the regulatory recognition of investments undertaken by grid operators, it does refer to the techno-economic aspects of creating a backbone and recognizes that pipelines' adaptations need to be stimulated with subordinated loans. Particularly new hydrogen pipelines jointly owned by gas TSOs of the countries involved, would need about 50% grants/subsidies and 50% subordinated loans. The development of new hydrogen infrastructure, however, is envisioned by the EU Hydrogen Strategy in the second phase of hydrogen production scale-up, covering the period from 2025-2030. In the first phase of the Strategy, retrofit is considered a more cost-effective solution, using existing infrastructure as natural gas demand reduces.

The *EU Commission Questions and Answers on the Hydrogen Strategy for a climate neutral Europe,* explains how the strategy will support investments in the hydrogen economy, making explicit mention to the launch of the European Clean Hydrogen Alliance and the instruments to be used for investing in hydrogen (e.g. Next Generation EU, REACT-EU etc.).

The European Commission's report on *the impact of the use of the biomethane and hydrogen potential on trans-European infrastructure*, is a study containing three explorative scenarios and assumptions regarding the use of electricity, methane and hydrogen to analyze the impact on the gas infrastructure. In doing so, the paper analyses the regulatory framework and readiness level for gas infrastructure. It also analyses the specific policy and regulatory framework for renewable gas of selected Member States. The paper concludes that authorities should improve the transparency and the vision on the future infrastructure constraints and costs of the energy system, as a key element for preparing the adaptation of gas infrastructures to the energy transition. Further, planning of new energy infrastructure should be future-proof, accounting for optimal use of existing infrastructure and guaranteeing cost-efficiency across all available options (roll-out of hydrogen networks, alternative flexibility solutions such as demand response, reverse flow projects, etc.), whilst at the same time considering national differences. The paper also calls for a more integrated planning, both between TSOs and DSOs (including storage and LNG operators), and between the electricity and gas sectors (for limiting the risk of stranded assets for example). This practically translates into future regulatory frameworks that foresee the development of national and European network development plans (NDPs and TYNDPs) in a coordinated way between electricity and gas, ensuring cross-sectoral optimization of investments and overall cost efficiency. To this end, the paper suggests that TEN-E and CEF regulations should support projects facilitating the integration of renewable gas (P2G projects, connections of renewable gas production to the grid, cross-border transmission projects or facilities allowing renewable gas reverse flows from DSO to TSO grids). Such projects should be eligible to apply for PCI status. Particular emphasis is placed on the regulatory framework pertinent to the development of power to gas facilities, which should provide for the TSOs to build P2G facilities as demonstrator or as industrial unit, and operate them as service provider for market parties, through for instance a tolling agreement. For this to happen, regulatory changes would need to foresee such facilities in the TSO regulated asset base (RAB[17]) and to implement regulated open and non-discriminatory third-party access to the P2G conversion facilities. Furthermore, explicit mention is made on dedicated hydrogen networks. Specifically, since under the current conditions it is unlikely that private parties will invest in new hydrogen transport infrastructure, it might be

[17] In most EU MS, the capital remuneration of gas network operators depends, amongst others, on the Regulated Asset Base

appropriate to extend the role of TSOs/DSOs and to allow them to develop and operate hydrogen networks under the same regulatory framework as natural gas networks. This would include regulated non-discriminatory third party access to support and further develop the internal European energy market, including for hydrogen.

The report on *Technical and Economic conditions for injecting hydrogen into natural gas networks (GRTGaz et al., 2019)*, is a work carried out by French operators for assessing the network adaptation costs of hydrogen injection into the grid. The report focuses on the techno-economic aspects of network adaptations with regulatory implications to be considered by the Minister of State, the Minister for Ecological and Inclusive Transition but also by the French Energy Regulatory Commission, as well. The paper provides a summary of adaptation costs at different stages of the hydrogen value chain and relative to different hydrogen content thresholds. Specifically, the report identifies four thresholds, namely at 6% of hydrogen, 10%, 20% and 30%, where investments should take place:

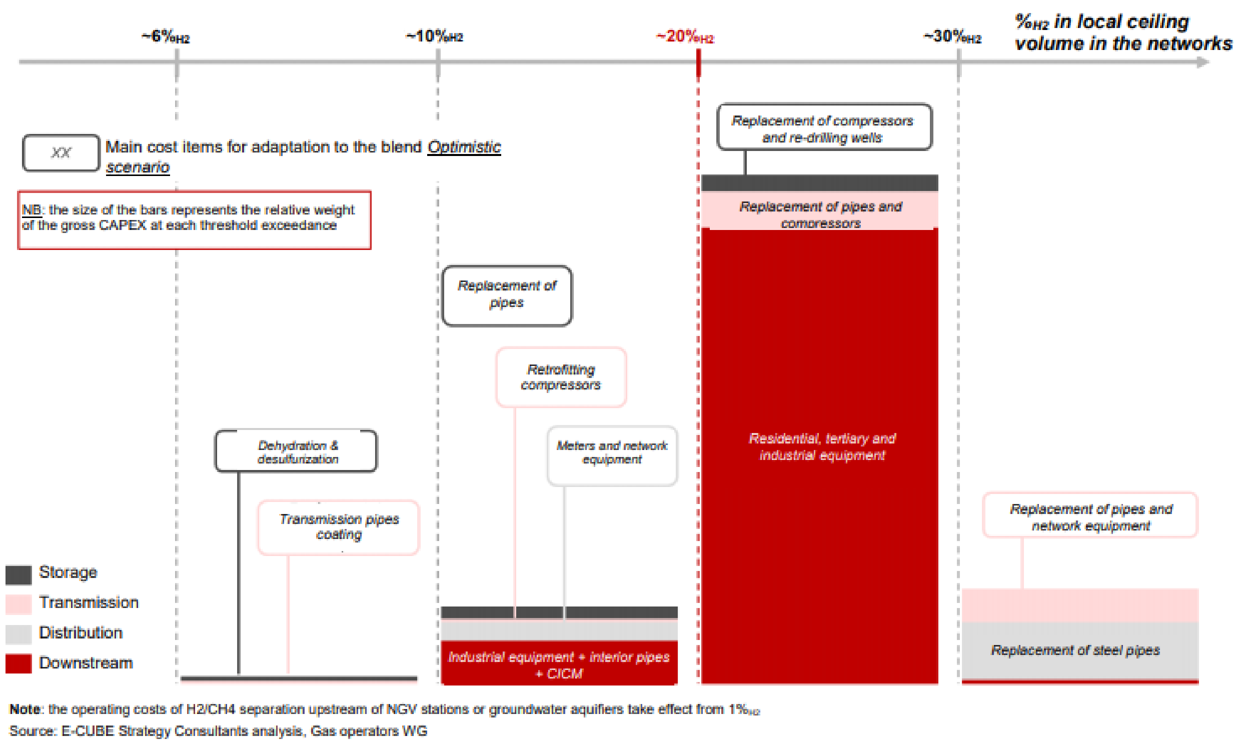


Figure 1. Summary of adaptation costs at different stages of the hydrogen value chain and considering different hdyrogen

Within this context, the report suggests that operators should coordinate and share R&D efforts for all the technical injection routes identified. R&D work should initially extend the zones suitable for the injection of 6% hydrogen mixture, with the threshold gradually increasing. Furthermore, it is suggested that these R&D investments are integrated into the expenditure covered by the tariffs so that natural gas infrastructures can play their full role in the development of the French and European hydrogen sector, and retain their value in the energy transition. This is also where the provision of European funding for joint R&D actions also comes into play. For instance, the report mentions the 2 million euros support offered by the Fuel Cells and Hydrogen Joint Undertaking (FCHJU), in support of the projects addressing the subject: "Systematic validation of the ability to inject hydrogen at various admixture levels into high-pressure gas networks in operational conditions".

The Gas Goes Green Initiative: Delivering the pathway to net zero report, sets out a detailed plan to deliver solutions that allow the existing pipelines in the UK to move away from natural gas and towards clean gases. Thus far, UK gas networks have submitted their business plans to the energy industry regulator Ofgem, for the coming regulatory period starting from April 2021. Within the workstreams organized for the transition preparation, the report identifies joint network planning for Great Britain's gas infrastructure needs. Indeed, innovation projects have been undertaken thus far by the gas networks and their cooperation with green gas producers and suppliers. Building on these projects is required for delivering a timeline for the investments needed to deliver net zero emissions.

The *European Gas Infrastructure can help deliver the EU Hydrogen Strategy (GIE)* report recommends the amendments of relevant EU legislation (e.g. TEN-E regulation) to enable network owners to operate several categories of gases, including hydrogen, and providing them with incentives to adapt their infrastructures to cope with the coexistence of different gases. It also suggests the creation of a roadmap for hydrogen gas assets readiness developed in close cooperation with the gas infrastructure and the electricity sector.

The Dutch Government Strategy on Hydrogen, which is a prelude of the hydrogen programme to be jointly outlined and implemented with stakeholders, stresses the fact that any network for the transport and distribution of hydrogen will have some of the characteristics of a natural monopoly. With part of the existing gas grid planned to be used for the transport of hydrogen, the government will be involved along with network operators and network companies in assessing the conditions under which this can be achieved. In doing so, the government will consider the network development within the broader North –western European hydrogen market context, with a view of creating a hub in the Netherlands for hydrogen provision to the neighbouring countries (particularly through the connection with Germany).

Germany's National Hydrogen Strategy, includes an action plan covering, amongst others, infrastructure and supply. The aim is to use the natural gas infrastructure that can be adjusted and backfitted to make it hydrogen ready, or create dedicated hydrogen infrastructure. To that end, Germany aims to start from the market exploration procedure as a first step towards preparing the regulatory basis required for the construction and expansion of hydrogen infrastructure. Further, the strategy mentions the need for better linkage of the electricity, heat and gas infrastructure, and hence, it aims to shape the planning, financing, and the regulatory framework in a way that makes it possible to coordinate these different parts of the infrastructure and develop them as required in line with the needs of the energy transition and in a cost-efficient way.

4.3 The time horizon of the regulatory period

Under this assessment area, we examined the time horizon of the proposed or existing regulatory period. To this end, we considered specific timeframes, but also priority levels, relevant strategies and policies which refer to target years and trial periods within regulatory sandboxes. Table 8 lists the relevant key considerations addressed in each paper.

Table 8. Key aspects covered with respect to the time horizon of the regulatory period

Material	Key regulatory aspects covered

Hydrogen Strategy for a climate neutral Europe	<u>Identification of priority levels &</u>
	<u>Timeframes and objectives:</u>
	• Development of a hydrogen ecosystem in three phases:
	  • 1st Phase (2020 – 2024): Installation of renewable hydrogen electrolysers – Focus on production
	  • 2nd Phase (2025 – 2030): Increase in renewable hydrogen electrolysers capacity – Focus on repurposing of existing gas infrastructure and the development of larger storage facilities
	  • 3rd Phase (2030-2050): Maturity phase and large-scale deployment of hydrogen

Material	Key regulatory aspects covered
The Bridge beyond 2025	Identification of priority levels & Strategies, policies, etc.: • Policy priorities without mention to specific milestones (given its early release): ➢ Access and market monitoring; Governance of infrastructure and oversight of existing and new entities; Dynamic regulation for new activities and technologies; Transmission Tariffs and cross-border capacity allocation
NRA Survey on Hydrogen, Biomethane and related network adaptations	Timeframes and objectives & Strategies, policies, etc.: • Review of Member States' NDPs and other policy papers, which stipulate plans for specific timeframes (e.g. Belgium's NDP includes plans for investments by 2024 for measuring hydrogen concentration in transported gas) • Need for setting H2 levels in blends by specific target years
EFET comments on the Roadmap for an EU Hydrogen Strategy	Identification of priority levels & Strategies, policies, etc.: • Policy priorities without specifying timeframe of implementation. TSOs can facilitate optimization of grid infrastructure at transmission and distribution levels and increase integration of power to gas technologies
Hydrogen generation in Europe, Overview of costs and key benefits	Timeframes and objectives: • Identification of investment opportunities across the hydrogen value chain over a specified time horizon, from 2020-2050
European Hydrogen Backbone	Timeframes and objectives: • A roadmap for the creation of a dedicated hydrogen infrastructure by 2030, 2025 and 2040 from a technical perspective
The 2050 Roadmap for gas grids	Timeframes and objectives: • Notions about the regulatory framework to be developed by 2050, without specific milestone recommendations Sandbox frameworks and trial periods: • Development of a framework for regulatory sandbox at EU level, with the supervision of the NRAs at national level to enable network operators to develop R&D and pilot projects
Public Consultation on Regulatory challenges for a sustainable gas sector	Strategies, policies, etc.: • Indirectly addressed in the context of the TYNDP identification as the cornerstone of the EU strategy of networks development
Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a	Identification of priority levels & Timeframes and objectives: • Key priority: harmonizing regulation to inject hydrogen into the natural gas network, and enabling the continued use of gas infrastructure

Material	Key regulatory aspects covered
climate neutral economy	
Hydrogen 2030: The blueprint	<u>Timeframes and objectives:</u> • Provides estimates of the total needed investments in building a hydrogen system up to 2030
Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure	<u>Timeframes and objectives:</u> • Regulatory implications for the period up until 2030 (mid-term) and 2050 (long-term) <u>Sandbox frameworks and trial periods:</u> • Need for supporting regulatory framework for revenue certainty for hydrogen network operators • Regulatory sandboxes for P2G projects • Tailored regulatory regime to experiment with different technologies • Need to establish cost recovery framework of investments by TSOs
Technical and Economic conditions for injecting hydrogen into natural gas networks	<u>Identification of priority levels:</u> • Priority levers starting from setting blending rates according to specificities of locations within France • Work towards 100% hydrogen clusters • Launch progress reports every 5 years
Germany's National Hydrogen Strategy	<u>Timeframes and objectives:</u> • First ramp-up phase up until 2023 to establish the basis for a well –functioning market • Phase between 2024-2030 to stabilize the domestic market <u>Sandbox frameworks and trial periods:</u> • Regulatory sandboxes for P2G projects

The *Hydrogen Strategy for a climate neutral Europe* envisages a viable solution for decarbonizing different sectors with clean hydrogen over time. It is recognized that the hydrogen ecosystem is likely to develop through a gradual trajectory, hence, in this paper the strategic objectives are set out to develop in three distinct phases. The first phase, covering the period from 2020 to 2024, foresees the installation of at least 6 GW of renewable hydrogen electrolysers in the EU and the subsequent production of up to 1 million tonnes of renewable hydrogen. This means that infrastructure needs for hydrogen transportation remain limited, as initially demand will be met by production in close proximity to consumption sites. Yet, at this stage the planning of medium range and backbone transmission infrastructure should begin. For this phase, policy development will focus on creating a liquid and efficient hydrogen market and on incentivizing renewable and low carbon hydrogen production. The second phase envisaged, between 2025 to 2030, foresees the installation of at least 40GW of renewable hydrogen electrolysers by 2030 and the subsequent production of up to 10 million tonnes of renewable hydrogen in the EU. During this phase, it is expected that the existing gas grid will be repurposed for transporting hydrogen over longer distances and thus, the development of larger scale storage facilities would be deemed necessary.

This, in terms of regulatory focus, would require EU's support to stimulate investments and to create a competitive hydrogen market, promoting cross-border trade and efficient allocation of hydrogen supply amongst sectors. The third phase, covering the period from 2030 to 2050, foresees the maturity of renewable hydrogen production and deployment of hydrogen at large scale. The *EU Commission Questions and Answers on the Hydrogen Strategy for a climate neutral Europe,* also refers the Hydrogen Strategy's clean hydrogen development trajectory (2020 – 2024, 2024 – 2030 and 2030 -2050)

The Bridge beyond 2025, on the other hand, does not set out a clear time frame with specific milestones, having been published in as early as November 2019. Rather, it highlights four thematic areas in need of regulatory attention beyond 2025, as priorities, amongst which, the governance of infrastructure and oversight of existing and new entities.

The *NRA Survey on Hydrogen, Biomethane and related network adaptations*, includes the notion of a regulatory timeframe in the sense that it looks at Member States' NDPs and other policy papers, which stipulate plans for specific regulatory timeframes. Indicatively, Belgium's NDP for 2020-2023, sets out a program to adapt/invest in new installations to measure hydrogen concentration in transported gas, based on an incentive regulatory approach of tariff setting regime. The survey also highlights that there are currently H2 blending targets for the TSOs, although in some MSs there are ongoing studies and discussions on possible blending targets.

In the *EFET comments on the Roadmap for an EU Hydrogen Strategy*, the regulatory period timeframe is only indirectly addressed, in the sense that the paper sets out policy priorities. Starting from setting an economy wide neutrality objective at EU level, strengthening the EU ETS and utilizing market-based mechanisms, to ensuring pan-European coordination and cross border implementation of any support schemes for renewable and low carbon gases and creating a level playing field between power and gas systems. Within the market-based mechanism policy, it suggests the facilitation of grid infrastructure optimization at transmission and distribution levels and increasing integration of power and gas infrastructure. It does not, however, set out a clear policy timeframe for each of these priorities.

Hydrogen generation in Europe, Overview of costs and key benefits, deals more with the techno-economic evidence for identifying investment opportunities across the hydrogen value chain over a specified time horizon, from 2020-2050, rather than the regulatory framework in need to support these investments.

Similarly, the *European Hydrogen Backbone - How a dedicated Hydrogen infrastructure can be created*, envisages the gradual creation of a dedicated hydrogen infrastructure by 2030, 2035 and 2040, approximating the rationale of the EU Hydrogen Strategy, but without policy or regulatory notions.

The *2050 Roadmap for gas grids*, is a paper developed in line with the EU Energy Union priorities itself, and as such, it contains notions regarding the regulatory framework in need to be developed by 2050, without setting out milestones for specific target years. The Roadmap does, however, build on the TSOs' views to achieve net zero GHG emissions and provides policy recommendations and a regulatory framework review, as important steps towards this direction. Indicatively, it proposes the development of a framework for regulatory sandbox at EU level, with the supervision of the NRAs at national level, so as to enable network operators to develop R&D and pilot projects necessary to spark the transition towards hydrogen networks.

The *Public Consultation on Regulatory challenges for a sustainable gas sector*, refers to the EU regulatory framework in the context of the TYNDP that was elaborated within the Third legislative package. This paper identifies the TYNDP as the cornerstone of the EU strategy of networks development, but it also highlights the grey areas when it comes to the involvement of amongst others, the TSOs. The Consultation is based more on the interpretation of the current framework and its implications, but no other specific regulatory time horizons are proposed.

In the same spirit, the *Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy*, generally identifies the need for a long-term regulatory framework, in support of harmonizing regulation to inject hydrogen into the natural gas network, and enabling the continued use of gas infrastructure, as key priorities. Nevertheless, milestones within specific time horizons are not mentioned.

Hydrogen 2030: The blueprint provides estimates of the total needed investments in building a hydrogen system up to 2030, that could be used as a basis for designing policies and support schemes in the EU and its MS. The paper itself has a different scope however, and does not pinpoint any regulatory priorities within the specific timeframe examined.

The European Commission's report on *the impact of the use of the biomethane and hydrogen potential on trans-European infrastructure*, discusses the regulatory recommendations assuming ambitious reduction targets for GHG net emissions reduction of 49% by 2030 and 100% by 2050, as compared to the 1990 levels for the entire energy system. In all its scenarios the report assumes zero hydrogen admixture into the gas networks by 2050. This is because, a low admixture of 10-20[18] vol% would not contribute significantly to the required CO_2 emission reduction targets, nor would it reduce the cost associated with novel construction or retrofitting significantly, amongst other reasons. Hence, all regulatory recommendations in this paper broadly correspond to a short-term period (by 2030) and a longer-term period (by 2050). Within the regulatory timeframe context, the paper makes explicit mention of the revenue regulatory framework. Specifically, under the current regulatory framework, the recovery of the reasonable cost of service for system operators is assured, providing a level of certainty in the short-term (given that a typical regulatory period ranges between 3-5 years). In order to incentivize innovation of TSOs and DSOs in the medium to long term, however, a supporting regulatory framework is needed. For instance, in some countries where P2G is most developed, there are plans to launch regulatory sandboxes within the regulatory framework to provide specific incentives and a tailored regulatory regime to experiment with innovative technologies. Further to that, the current framework guarantees in principle the cost recovery of efficient investments and operational expenses made by TSOs, yet, there is no framework for hydrogen networks and there is also no relevant provision in the TEN-E regulation. This practically means that there are no priority corridors relevant to hydrogen within the regulation implementation timeframe. Lastly, the paper concludes on the need for a European roadmap for the transition from a fully methane-based gas system to a gas system with distinct hydrogen and methane network systems by 2050. Based on the study's results, strategies for a fully decarbonized gas system by 2050 should be developed describing cost effective transition pathways in the medium term (2030). Notably for hydrogen, further analysis of possible development strategies and pathways for a stepwise development of 100% hydrogen network islands[19] that eventually grow into one large network in the future is recommended.

The report on *Technical and Economic conditions for injecting hydrogen into natural gas networks (GRTGaz et al., 2019),* sets priority levers to prepare gas systems for the integration of hydrogen and synthetic methane:

1. Identify suitable areas in which the 6% blending rate is applicable and when conditions are met, adapt the gas specifications to inject 10% by 2030 and later 20% and on

[18] The paper assumes that any percentage above 20 vol% would require major refurbishments and hence it would not make sense from an economic standpoint. According to some experts and TSOs, even a 20 vol% of hydrogen admixture would not be cost-efficient, let alone any percentage above that

[19] The paper suggests favourable regulation first at DSO level in individual MS that allow the creation of locally ringfenced sections of the network that run on higher hydrogen concentrations, favourably at 100% hydrogen. Promoting such "islands" will provide very valuable learnings and operational experience and enable a scale-up by connecting adjacent islands over time.

2. Invite operators to coordinate and share R&D efforts for all the technical injection routes. Ensure that the corresponding costs are covered in their regulated economic models under the existing processes. This was meant to occur in the 2nd half of 2019
3. Set a specification of 10% blended hydrogen as a sector-wide target by 2030, in order to mobilise equipment manufacturers and downstream users and to steer operator investments on a case-by-case basis. This was also meant to occur in the 2nd half of 2019
4. Lead a hydrogen injection working to bring together gas chain stakeholders and government services in conjunction with hydrogen producers, to facilitate the implementation of the initial hydrogen projects
5. Mount a unified defence of the French position in European standardization work on infrastructure and downstream equipment
6. Carry out assessment of the externalities of injecting hydrogen into the networks, including a life cycle analysis. This was meant to occur in the 1st half of 2020
7. Integrate the role of gas infrastructures in the development of hydrogen into energy blend forecasting and implement a specific work programme on the coupling of gas and electricity networks
8. Define and implement a favorable framework for experimenting with the development and operation of the first 100% hydrogen clusters
9. Create a framework for the development of P2G in the event of market failure
10. Establish regular work progress reviews between the operators and the State services and update the report every 5 years

Germany's National Hydrogen Strategy, places the provisions of its accompanying Action Plan as a basis for private investments in hydrogen generation, transport and use. The plan foresees, in a first ramp-up phase, which extends to 2023, that the Federal Government will take a number of measures focusing on laying the ground for the development of a well-functioning domestic market. The next phase, due to begin in 2024, is about stabilizing the newly emerging market all the way until 2030. The set of measures to be taken during the first phase, also includes the assessment of using existing infrastructure and creating new ones. Further to this, a new cross-ministry research campaign called Hydrogen Technologies 2030, will be launched starting from 2020, which will include key elements such as regulatory sandboxes for the energy transition, so as to bring PtX technologies that are close to market to an industrial scale and thus, accelerate the process of innovation transfer.

4.4 The benefits expected from the adaptations in developing a hydrogen network

4.4.1 Evaluation of infrastructure investments

Any regulatory decisions on investments must be supported by systematic planning early on. This section discusses the extent to which hydrogen infrastructure development is discussed within the context of optimal investment decision. Hence, under this section, we are looking into the investment appraisal methods, either those that have been conducted and presented in the papers or those that the material recommends to be considered for future investment decisions. Table 9 lists the investment appraisal methods covered in the material reviewed.

Table 9. Key aspects covered with respect to the evaluation of the infrastructure investments

Material	Key regulatory aspects covered
The Bridge beyond 2025	Cost-Benefit Analysis: • Suggestion to factor in sustainability effects of new investments in CBA • ACER to be able to issue clear binding CBA methodology guidelines
Hydrogen generation in Europe, Overview	Other investment appraisal approaches:

Material	Key regulatory aspects covered
of costs and key benefits	• Report on the cost of hydrogen transmission and storage infrastructure and other investments across the value chain, and societal benefits in terms of employment opportunities created
Public Consultation on Regulatory challenges for a sustainable gas sector	Cost-Benefit Analysis: • Need for a sound CBA methodology to validate future investments • ACER to be able to issue clear binding CBA methodology guidelines
Hydrogen Europe Vision	Cost-Benefit Analysis: • Broad mention of the need for a sound CBA methodology to validate future investments
Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure	Cost-Benefit Analysis: • The TEN-E guidelines note that gas PCIs can potentially support the development of renewable sources, yet thus far, none of the gas PCIs published make reference to the integration of hydrogen
Technical and Economic conditions for injecting hydrogen into natural gas networks	Other investment appraisal approaches: • Recommends carrying out an assessment of the externalities of injecting hydrogen into the networks (the GHG emissions avoided, the improvement in the trade balance for the portion of hydrogen produced in France, and the job creation and other local economic benefits)

The Bridge beyond 2025, on the new infrastructure planning, stresses the fact that the CBA methodology in the case of infrastructure planning, including hydrogen networks, needs to be adapted to ensure that sustainability effects of new investments are properly accounted for. Specifically, it suggests that the CBA should include a full assessment of the decarbonization effects and how they are translated in monetary terms, and that it should also be applicable to asset decommissioning as well as repurposing of natural gas assets. In support of this, ACER proposes to be authorized to set binding guidelines for the CBA methodology, require ENTSOs to amend the methodology where needed and document any models used in the CBA, whilst allowing for third parties to run the analysis independently.

The *Hydrogen generation in Europe, Overview of costs and key benefits* does not include regulatory recommendations for investment appraisal methods. Rather, it is an appraisal report itself, which builds on the latest published data for investment opportunities across the hydrogen value chain. It covers the costs and the associated benefits in terms of employment opportunities. Within this context, the paper has gathered and normalized relevant data to deduce the cost of hydrogen transmission and storage infrastructure, amongst others. It does so, both considering the refurbishment of existing infrastructure and the creation of new dedicated hydrogen infrastructure. The paper also derives the results with respect to employment created, both directly and indirectly, across the value chain.

The *Public Consultation on Regulatory challenges for a sustainable gas sector*, discusses the infrastructure investments and regulation. The paper stresses the need for careful assessment of new investment decisions and assesses whether the current investment framework is robust enough to support future investment needs. Within this context, CEER proposes better coordination between the Capacity Allocation Mechanisms Network Codes' (CAM NC) incremental capacity approach for new investments (based on market tests) and the Projects of Common Interest (PCI) selection process, based on CBA. The paper argues that a stronger oversight by ACER and NRAs is required in terms of the TYNDPs, CBA methodology and underlying scenarios, which should not be influenced by the sole interest of the TSOs. The paper supports ACER's position on having the authority to issue binding guidelines for the CBA methodology.

Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy, only broadly refers to the costs-benefit analysis as a condition for investments in power to gas and CCS assets. Yet, it does not make any specific recommendations on the methodology to be followed.

The European Commission's report on *the impact of the use of the biomethane and hydrogen potential on trans-European infrastructure*, discusses the TEN-E guidelines which lay down the procedure and cost benefit analysis to identify potential PCIs. Gas infrastructure is one of the main energy infrastructure categories in the TEN-E guidelines, including underground storage facilities and pipelines for natural gas, but excluding pipelines at the distribution level and not explicitly including hydrogen transport infrastructure nor conversion projects, such as P2G. Nevertheless, the sustainability criteria for the evaluation of gas infrastructure do include the contribution of a project to also support P2G. This has been included in the 2nd ENTSOG methodology for CBA analysis, which provides for the sustainability criteria of integration of biomethane and other synthetic gases to be considered in the project benefits. Thereby, the TEN-E guidelines do note that gas PCIs can potentially support the development of renewable sources, yet thus far, none of the gas PCIs published make reference to the integration of hydrogen.

The report on *Technical and Economic conditions for injecting hydrogen into natural gas networks (GRTGaz et al., 2019)*, recommends carrying out an assessment of the externalities of injecting hydrogen into the networks. The report itself includes an assessment of the adaptation costs related to infrastructures, amongst others. The relevance of these costs, however, must be assessed with regard to the externalities and services arising from the injection of hydrogen into the networks. In particular, the report focuses on three assessment areas: the GHG emissions avoided, the improvement in the trade balance for the portion of hydrogen produced in France, and the job creation and other local economic benefits. To that end, an analysis of the hydrogen life cycle according to the different types of production and injection routes must be carried out to assess environmental externalities.

4.4.2 Other benefits expected from the adaptations in developing a hydrogen network

In terms of expected benefits resulting from the implementation of the adaptations needed to enable the handling of hydrogen, it is noted that this thematic area is more broadly represented in most papers. Under this assessment area, we have considered the acknowledgement of benefits from an environmental perspective, as well as in terms of security of supply, mutual strengthening of the electricity and gas sectors and socio-economic benefits.

Table 10. Key aspects covered with respect to the benefits expected from the adaptations in developing a hydrogen network

Material	Key regulatory aspects covered
Hydrogen Strategy for a climate neutral Europe	<u>Flexibility and security of supply:</u> • Role of infrastructure in terms of cyclical or seasonal storage • Facilitation of cross-border trade for an open and competitive market
	<u>Environmental benefits:</u> • GHG emissions reduction

Material	Key regulatory aspects covered
	<u>Job creation and other socio-economic benefits:</u> • EU economy recovery
The Bridge beyond 2025	<u>Flexibility and security of supply &</u> <u>Environmental benefits:</u> • Level playing field between conversion and storage facilities to realize recognition of security of supply and environmental benefits
NRA Survey on Hydrogen, Biomethane and related network adaptations	<u>Job creation and other socio-economic benefits:</u> • Danish NRA suggests that TSOs should select optimal locations for power to gas units, to harness the socio-economic benefits of grid infrastructure
2050 Roadmap for gas grids	<u>Mutual strengthening of electricity and gas networks through the production and injection of hydrogen,</u> <u>Flexibility and security of supply &</u> <u>Other benefits:</u> • Suggests the application of regulatory sandboxes to support the early business models and technologies' scale up, as a means to realize these benefits
Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy	<u>Mutual strengthening of electricity and gas networks through the production and injection of hydrogen,</u> <u>Flexibility and security of supply &</u> <u>Other benefits:</u> • Suggests the creation of a single harmonized regulatory framework in support of infrastructural coupling, and the removal of regulatory barriers to allow for investments in the relevant technologies, as a means to realize these benefits
EU Commission Questions and Answers on the Hydrogen Strategy for a climate neutral Europe	<u>Job creation and other socio-economic benefits:</u> • The Commission has proposed recovery plans for unlocking investments and fostering sustainable growth and jobs • It sees hydrogen as a means to recover from the Covid crisis
Technical and Economic conditions for injecting hydrogen into natural gas networks	<u>Mutual strengthening of electricity and gas networks through the production and injection of hydrogen:</u> • Public authorities to set up a framework bringing together gas and electricity network operators with a view to achieving a consolidated French vision and thus, bringing about the associated sector integration benefits.

The *Hydrogen Strategy for a climate neutral Europe* mentions the role of infrastructure in terms of cyclical or seasonal storage, covering peak demand, securing hydrogen supply and allowing for electrolysers to operate flexibly. Furthermore, infrastructure will enable cross-border trade thus leading to an open and competitive liquid market ensuring affordability and security of supply. The hydrogen ecosystem, if efficiently developed, will contribute to the greenhouse gas emissions reduction and the recovery of the EU economy, whilst creating new opportunities for research and innovation, allowing for Europe to expand its technological leadership and help creating jobs across the full value chain.

The Bridge beyond 2025 concludes that particular focus should be placed on creating a level playing field between conversion and storage facilities across the energy sector, to ensure, amongst others, equivalent recognition of environmental and security of supply benefits. In terms of current status, the paper mentions ACER's Gas Target Model (GTM), which specifies the steps needed to realize liquid and dynamic gas markets, thus enabling all EU consumers to benefit from secure gas supplies and effective competition. For achieving improvement in market functioning, the paper also concludes that a new system of dynamic and targeted regulation should be established in EU law.

The NRA Survey on Hydrogen, Biomethane and related network adaptations, refers to country specific benefits, as reported by the respective MS NRAs. Amongst those, only the Danish NRA, reports that the TSOs should be a part of planning the optimal geographical location of Power to Gas units, by providing information of grid constraints and optimizing in order to achieve socio economic benefits in relation to infrastructure developments.

The *EFET comments on the Roadmap for an EU Hydrogen Strategy* lists five policy priorities in order to realize the benefits of a cost-effective decarbonization of the EU economy, without specifying what benefits can be leveraged from each policy option.

ENTSOG's *2050 Roadmap for gas grids*, generally considers the benefits of hybrid energy systems: the maximized integration of renewables, the flexibility brought in balancing variable input from wind and PV generation units, the mutual strengthening of the electricity and gas sectors, the sectoral integration of renewables, resilience of the energy system in terms of cybersecurity and the creation of a more robust system overall. Within the context of creating a hybrid energy system with the aforementioned benefits, the paper proposes the application of regulatory sandboxes to support the early business models and technologies to scale up.

Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy, refers to the societal benefits arising from the adaptation of existing gas infrastructure for transport and storage of hydrogen. Sectoral integration and the creation of synergies is also foreseen across the industry, heating, agriculture and transport sectors. In its elaboration on sectoral integration, the paper highlights the need for a single harmonized regulatory framework in support of infrastructural coupling, and the removal of regulatory barriers to allow for investments in the relevant technologies.

The *EU Commission Questions and Answers on the Hydrogen Strategy for a climate neutral Europe,* refers to hydrogen as a means for recovery from the COVID-19 crisis. Within this context it mentions the Commission's proposed recovery plans for unlocking investments and fostering sustainable growth and jobs.

The report on *Technical and Economic conditions for injecting hydrogen into natural gas networks (GRTGaz et al., 2019,* recommends integrating the role of gas infrastructures in the development of hydrogen into energy blend forecasting and implementing a specific work programme on the coupling of gas and electricity networks to create inter-sectoral benefits. Gas operators in France have already made themselves available to assist public authorities in mobilizing gas and electricity ecosystems. They are currently working with industry stakeholders to assess and optimize the role of natural gas infrastructures in the development of decarbonized hydrogen and the various associated uses, with the aim of helping achieve carbon neutrality by 2050 at an optimal cost. Hence, operators urge the public authorities to set up a framework bringing together gas and electricity network operators with a view to achieving a consolidated French vision and thus, bringing about the associated sector integration benefits.

4.6 Market, economic and financial terms and conditions to be accounted by regulators for hydrogen

Under this section, we look into enablers and barriers to market entry, including institutional and legal issues, financial and administrative burdens and proposed ways to address them. Table 11 lists the key aspects covered in each paper.

Table 11. Key aspects covered with respect to market, economic and financial terms and conditions to be accounted by regulators for hydrogen

Material	Key regulatory aspects covered
Hydrogen Strategy for a climate neutral Europe	Enablers: • Recommendations: ➢ Direct and transparent market-based mechanisms ➢ Reflective price signals ➢ Revision of internal gas market legislation for competitive decarbonized markets ➢ Common international market rules
The Bridge beyond 2025	Barriers: • Weak competition • Institutional and structural issues • Licensing and registration issues Enablers: • Recommendations: ➢ More effective Gas Target Model ➢ More effective Market Monitoring • System of mutual recognition for wholesale market authorizations and licenses across the EU
EFET comments on the Roadmap for an EU Hydrogen Strategy	Enablers: • Recommendations: ➢ Deployment of market-based mechanisms and adaptation of market instruments
2050 Roadmap for gas grids	Barriers: • Current market conditions do not seem to sufficiently support the up-scaling of commercial activities needed for optimizing gas and electricity infrastructure functioning (e.g. lack of incentives) Enablers: • Recommendations: ➢ Funding access, ownership unbundling ➢ Other solutions within a regulatory sandbox

Material	Key regulatory aspects covered
CEER Consultation paper on the regulatory challenges for a sustainable gas sector	<u>Barriers:</u> • Illiquidity in certain markets
	<u>Enablers:</u> • Recommendations: • Regulation of access to infrastructure (Network usage rules and tariffs)

Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy	<u>Enablers:</u>
	• Recommendations:
	  ➢ Launch of tenders for all players to enable investments through support mechanisms
	  ➢ Alternatively, framework for TSOs and DSOs to directly invest as a regulated activity, until market is mature enough to open to competition
	  ➢ Regulatory regime accounting for specific market conditions
	  ➢ Launch of a new gas package for a possible hydrogen market design target model

Towards the new age of gas networks	<u>Enablers:</u>
	• Unbundling of regulated (transmission, distribution, LNG or storage) and non-regulated activities (production, delivery) for TSOs and DSOs
	Non-discriminatory and transparent access to the network
	• Authorization obligations for the operation of hydrogen networks:
	  ➢ For admixtures of hydrogen: Authorization already covered as per Article 1(2) of the 2009 Gas Directive
	  ➢ For pure hydrogen network, provisions of the 2009 Gas Directive do not apply (lack of regulation)
	• Modifications on provisions on third-party network access for the inclusion of pure hydrogen networks

Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure	<u>Barriers:</u> • Not clear definition of P2G legal status (whether it is considered storage function or not), which leads to: ➢ Unclear unbundling rules
	<u>Enablers:</u> • Recommendations: ➢ Explore and value synergy potentials between regulated operators and enhance horizontal cooperation ➢ Clear definition of the legal status of P2G projects ➢ Clear unbundling rules. Potential for system operators to develop, own and operate P2G projects until the emergence of market interest in such projects
	<u>Barriers:</u> • Network companies prohibited from owning P2G projects

Material	Key regulatory aspects covered
The future of gas networks - key issues on debate	<u>Enablers:</u> • Recommendations: ➢ Change in law for network companies to own the hydrogen produced (if not prohibited from P2G projects) or for time limited derogations to allow a number of demonstration or small scale projects
Technical and Economic conditions for injecting hydrogen into natural gas networks	<u>Barriers:</u> • Difficult to set up P2G projects due to the lack of mechanisms to compensate services at a value guaranteeing profit
	<u>Enablers:</u> • Recommendations: ➢ Establish a transitional framework to enable projects deemed relevant within France to take shape
European Gas Infrastructure can help deliver the EU Hydrogen Strategy	<u>Enablers:</u> • Recommendations: ➢ Adjustment of levies, grid charges and taxes to reflect societal benefits provided by the gas infrastructure and avoidance of double charging ➢ Alignment of the EU Hydrogen Strategy with upcoming policy measures, particularly the Strategy for Energy System Integration and the Sustainable Finance and Taxonomy, to ensure a fully integrated market
Dutch Government Strategy on Hydrogen	<u>Enablers:</u> • Recommendations: ➢ Assess the regulatory aspects of the future role of the transmission system operator (Gasunie) ➢ Delegate temporary roles to help kickstart the hydrogen market, while upon market maturity more structural roles are envisioned ➢ Create statutory and regulatory flexibility for experiments to allow for network operators gain experience with handling hydrogen

The *Hydrogen Strategy for a climate neutral Europe* overall proposes the design of enabling market rules for the deployment of hydrogen, stressing the need to remove barriers for efficient hydrogen infrastructure development, amongst others. It also envisages direct and transparent market-based support schemes, allocated through competitive tenders, and a market whose price signals reward electrolysers for the services they provide to the energy system. The paper also mentions carbon contracts, in terms of the difference for renewable and low-carbon hydrogen, as a means of initial support for early deployment in various sectors, and particularly for renewable hydrogen it considers direct market-based support schemes and quotas. Further, in its 3-phase plan, the strategy stresses the need for the revision of the Trans-European Networks for energy and the review of the internal gas market legislation for competitive decarbonized markets, as well as for a sound infrastructure planning, on the basis of incentivizing investments. For the development of the market, the strategy mentions the nondiscriminatory access to hydrogen infrastructure, and the need for network operators to remain neutral in order to ensure a level playing field for market-based activities. Finally, the EU hydrogen strategy stresses the need for international cooperation in view of a global market, with common rules to avoid the arising of potential market barriers and trade distortions. This, as stated in the strategy, will be carried out in the context of an ongoing EU Trade Policy review.

The Bridge beyond 2025 recognizes that the Gas Target Model (GTM) has been generally successful. Nevertheless, market monitoring has shown that some markets are still characterized by weak competition or institutional and structural issues. Insufficient liquidity and administrative or legal market barriers to name a few, have hindered market functioning thus far. Hence, the paper suggests a more targeted and effective Gas Target Model. Specifically as far as the infrastructure are concerned, considerations regarding the strategic value of existing assets should apply, depending on the specifics of each market. For instance, a currently underutilized LNG terminal may prove more useful in the future, by providing additional security of supply, thus preventing the reliance on imports. ACER thus, proposes market monitoring as a basis upon which the sector evolution will occur. Although there already exists a data reporting system under the REMIT, more metrics are in order to ensure that a clear picture of the market is provided. The GMT provides certain tools to that end, such as various forms of market mergers, yet more tools are required. Another market aspect covered in this paper, refers to the licensing and registration issues and subsequent barriers that may arise. To remediate this, the Agency recommends a system of mutual recognition for wholesale market authorizations and licenses introduced across the EU.

The *EFET comments on the Roadmap for an EU Hydrogen Strategy*, in its five policy priorities for a cost effective decarbonization of the EU economy, broadly mention the deployment of market based mechanisms and adaptation of market instruments, whenever financial support for new, low carbon energy sources is considered, while respecting sectoral unbundling rules at the same time.

In the *2050 Roadmap for gas grids*, there is specific mention on the present market conditions, which do not seem to sufficiently support the up-scaling of commercial activities needed for optimizing gas and electricity infrastructure functioning. ENTSO-G proposes that TSOs should be considered for ownership of power to gas facilities, as a means of socializing costs as well as ensuring third party access to these infrastructure. Further, the current market conditions, do not offer sufficient incentives for developing necessary technologies. To that end, the deployment of regulatory sandboxes should be considered, in order to allow for hydrogen development activities to be handled under a more flexible regime. This includes, funding access, ownership unbundling, and others.

The *CEER Consultation paper on the regulatory challenges for a sustainable gas sector*, highlights the efficiency of the so far achievements in the gas market, in terms of transparency on transmission costs to be covered by transmission tariffs (Tariff Network Code) and the Gas Target Model. Nevertheless, it recognizes that there still illiquidity in certain markets. The paper also highlights the possibility of future market risks, calling for a detailed analysis of developments to understand the extent of such risks but also the potential opportunities that might arise. Lastly, the CEER consultation gives particular emphasis on the regulation of access to infrastructure. Particularly, network usage rules and tariffs are essential for energy regulators, and thus, in view of the upcoming challenges the gas sector will face, the paper highlights the relationship between the types of capacity products allocated and the methodology of tariffs calculation. Specifically, it is expected that, targeting climate neutrality, could lead to a decreasing and more variable gas demand in certain areas, and thus make some infrastructures become underutilized. Where tariffs combine capacity and distance, a decline in flows and capacity bookings, at certain interconnection points could lead to tariff increases, which could make price differential among some hubs higher than the current levels (especially If long-term contracts will be replaced by short term ones). Such higher reserve prices could reduce trading and market liquidity and consequently the income of TSOs. Such cases, should be monitored by NRAs and ACER in order to intervene with policy measures.

Hydrogen Europe Vision on the role of hydrogen and gas infrastructure towards a climate neutral economy, considers hydrogen as an integrating agent, bringing together multiple sectors. Within this context, power to hydrogen in particular, is seen as a non-regulated market with the typical use of a regulated asset as transport means through Third Party Access, without preventing the development of privately owned unregulated pipelines, serving dedicated customers. The paper proposes that authorities should launch a tender process open to all players to enable investments through support mechanism; the tendering process should be implemented in a way that will help maintain a level playing field across all actors. Nevertheless, if that fails, the paper suggests the alternative of a framework providing for TSOs and DSOs to directly invest as a regulated activity until market conditions are mature enough. For low carbon hydrogen, the paper foresees that, given the circumstances, authorities should define a regulatory scheme which takes into account the specific market conditions, ensure transparent access to infrastructure and limit regulatory activities to ensure they do not hinder the development of competitive markets in the long run. Further, the paper suggests the deployment of revenue supporting schemes temporarily, the increase in visibility of the electricity price and grid services income and an adequate internalization of CO_2 price, all as a means to ensure market success. Lastly, the paper suggests a new gas package for a possible hydrogen market design target model.

The GEODE paper *Towards the new age of gas networks*, explicitly mentions market entry considerations from the perspective of natural gas network operators. Within the context of unbundling as a means for non-discriminatory and transparent access to the network, it discusses natural gas undertakings where the same entity is entitled, either directly or indirectly to exercise control on at least one of the transmission, distribution LNG or storage activities, and at least on one of the functions of supply and demand. In terms of market entry, the paper delves into the authorization requirement terms, making a distinction between the hydrogen networks for the purpose of admixture and for the purpose of pure hydrogen networks. Specifically, for the purpose of accommodating admixtures in the natural gas network, the natural gas network operator has already been granted authorization as per Article 1(2) of the 2009 Gas Directive, and hence no additional authorization should be required. For a pure hydrogen network, the provisions of the 2009 Gas Directive do not apply, and hence in this case there is no obligation for authorization due to lack of regulation. In fact, this is the case for both new hydrogen networks and natural gas networks that have been repurposed for pure hydrogen. As such, the paper concludes that the rules on unbundling and market access allow the operation of a hydrogen network, as long as there is no conflict with the network expansion and network development regulations of the EU. Another aspect covered by GEODE, is the tariff setting for financing the hydrogen infrastructure. The 2009 Gas Directive only contains a few legal requirements for tariff determination, indicating that the fees must be calculated in a non-discriminatory, transparent but also cost-reflective way. Again, a distinction is made between networks for the purpose of admixtures and pure hydrogen networks. The paper concludes that the tariffs to be paid by network users of natural gas networks might as well be used to finance mixed gas networks, on the condition that the investment is deemed necessary. On the other hand, under the current legal regime, such financing is not possible for dedicated hydrogen networks, since it only refers to natural gas networks. Such barriers, can be countered by creating a framework for financing gas networks of all types.

The European Commission's report on the impact of the use of the biomethane and hydrogen potential on trans-European infrastructure, discusses the revenue regulatory framework, which as mentioned earlier, assures the recovery of the reasonable cost of service for the current regulatory period. That said, there is still a certain degree of uncertainty in the medium to long-term, depending on the volume of large investments in new or refurbished infrastructure or in case of significant fall in transported gas volumes. Hence, the paper suggests that as revenue levels are based on actual costs, measures should be considered to reduce costs and hence tariff increases due to falling transport volumes, e.g. by exploring and valuing synergy potentials between regulated operators (TSO/DSO) and/or horizontal (storage and network, electricity and gas) cooperation in order to reduce fixed costs, pending an analysis and potential changes to unbundling requirements. Further, NRAs should recognize within the RAB[20], investments which contribute to decarbonization of gas networks (e.g. hydrogen tolerant pipeline materials). Regarding the role of system operators in development of new technologies, currently in most countries the regulatory framework does not specify the legal status of P2G (whether it is classified as storage function or not), and thus a clear status and classification is recommended. As far as the ownership and operation of such facilities is concerned, the gas directive required storage to be unbundled from the activities of transmission and distribution system operators, yet the applicability of the unbundling is unclear because of the above mentioned uncertainty of the facilities' legal status. To remediate this, the paper also suggests the implementation of a market test framework to allow system operators, if there is no market interest, to develop, own and operate P2G as conversion services with separation from network activities, and to step out when there is market interest, whilst guaranteeing the cost recovery. The paper also highlights the importance of incentive regulation for TSO innovation (premium for high risk innovative projects, sandboxed, etc.). Particularly for the case of dedicated hydrogen networks, which are mostly relevant in the hydrogen scenario of the paper, it highlights the importance of defining whether these networks should be regulated or not, and to clarify the role of incumbent and new system operators in this regard. Lastly, the study discusses the how the network connection and access tariffs may influence the business case of renewable gas injection in the transmission and distribution level. Thus far, REDII requires network operators to publish connection tariffs for renewable gases. This, should be based on objective, transparent and non-discriminatory criteria. Further, there should be incentives in place for the injection of hydrogen, following priorities and/or according to added system benefits (e.g. priority access, etc.).

The future of gas networks - key issues on debate (the Oxford Institute for energy studies), also raises the issue of network companies being prohibited from participating in energy production and this could exclude them from participating from P2G projects, for instance. Yet, as the paper stresses, even if participation was allowed, a change in the law would still be required to allow network companies to own the hydrogen produced, or possibly, time limited derogations granted by the Commission could be applied to allow a certain number of demonstration or small scale projects to be developed. It suggests as possible alternatives, and independent hydrogen exchange or, when the derogations expire, the projects to be sold by the TSOs who are then compensated for the investments they have made.

The report on *Technical and Economic conditions for injecting hydrogen into natural gas networks (GRTGaz et al., 2019),* also focuses on the P2G economic models, which, as stated, can be difficult to set up in the absence of mechanisms to compensate services at a value guaranteeing profit. Currently, there is no mechanism to assess the value of coupling, and even less to remunerate it. The report underpins the need to establish a transitional framework to enable projects deemed relevant within France to take shape. This framework will secure their economic model by integrating the long periods linked to this type of investment and the current uncertainties as to the value of the services provided over time.

The *European Gas Infrastructure can help deliver the EU Hydrogen Strategy (GIE)* report in order to enhance the hydrogen market while increase the resilience and competitiveness of EU companies, suggests that EU gas infrastructure operators need, amongst others, the adjustment of levies, grid charges and taxes to reflect societal benefits provided by the gas infrastructure and avoidance of double charging. It also stresses the need for alignment of the EU Hydrogen Strategy with upcoming policy measures, particularly the Strategy for Energy System Integration and the Sustainable Finance and Taxonomy, to ensure a fully integrated market in view of the development of renewable and low carbon gases, like hydrogen.

[20] In most EU MS, the capital remuneration of gas network operators depends, amongst others, on the Regulated Asset Base.

The Dutch Government Strategy on Hydrogen, refers to the government's plans for examining the regulation of the future hydrogen market, including the operation of a potential future transport network. Within this context, the future role of the national transmission network operator, Gasunie, will be assessed. The regulation review will focus on potential temporary roles to help kickstart the hydrogen market, while upon market maturity more structural roles are envisioned. The National Climate Agreement already mandates that statutory and regulatory flexibility can be created for experiments to allow for network operators gain experience with handling hydrogen. To that end, the strategy envisages collaboration of network operators with market participants in order to explore a sustainable supply chain. Pertinent to that, a process has already been initiated to enable this through the General Administrative Order on Temporary Tasks.

4.7 New technologies, products and measures with a focus on those who address cross border barriers, for hydrogen handling

Under this section we examine the material in terms of inclusion of relevant regulatory aspects geared towards new technologies, products, measures, especially those that offer opportunities for enhancing cross-border flows. The majority of papers reviewed do not refer to specific technologies per se, or regulations regarding such technologies, hence our focus has shifted more on new products and measures with cross-border implications. Table 12 lists the relevant key elements included in the material reviewed, from guarantees of origin and other green certificates to the establishment of common gas quality standards across the EU.

Table 12. Key aspects covered with respect to new technologies, products and measures with a focus on those who address cross-border barriers

Material	Key regulatory aspects covered
Hydrogen Strategy for a climate neutral Europe	Guarantees of origin and other certificates: • Launch of certificates that facilitate EU wide trading
	Other solutions compatible with cross-border trade: • Launch of common quality standards in the EU and internationally • TYNDP to account for repurposing of infrastructure to address cross-border barriers • Establishment of international standardization bodies and global technical regulations
The Bridge beyond 2025	Other solutions compatible with cross-border trade: • Implementation of Tariffs Network Code (to avoid issues arising from tariff levels affecting cross-border trade) • Current market design to be addressed further in the EU legislation (e.g. harmonized capacity products) • Suggestion to be able to reduce reserve price in cross-border capacity allocation upon mutual agreement between NRAs
NRA Survey on Hydrogen, Biomethane and related network adaptations	Other solutions compatible with cross-border trade: • Establishment of standards across the EU regarding the H_2 concentration levels at cross-border interconnection points

Material	Key regulatory aspects covered
2050 Roadmap for gas grids	Guarantees of origin and other certificates: • Launch of certificates that facilitate EU wide trading
	Other solutions compatible with cross-border trade: • Coordination of cross-border and regional gas quality inventory and standardization of national and cross-border solutions, where digitalization could potentially play a key role
European Hydrogen Backbone	R&D and other projects of cross border relevance: • Green Octopus Project (IPCEI), which aims to create a 2000km hydrogen backbone by repurposing existing pipelines
Public Consultation on Regulatory challenges for a sustainable gas sector	Guarantees of origin and other certificates: • Standardization with respect to the GOs' function and use and cooperation of the issuing bodies
	Other solutions compatible with cross-border trade: • Specification of H_2 level standards to be injected into the gas networks
Hydrogen Europe Vision	Guarantees of origin and other certificates: • GO system to extend to renewable and low-carbon gases
	Other solutions compatible with cross-border trade: • Common gas quality standards
Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure	Other solutions compatible with cross-border trade: • Interoperability of gas networks • European Renewable Gas Registry (ERGaR) aims to enable cross-border trade and mass balancing of renewable gases, building on voluntary national registries
	Guarantees of origin and other certificates: • EU wide GO system
Future of Gas Networks – Key issues for debate	Other solutions compatible with cross-border trade: • Standardization, data quality, transparency and verification • Review of network codes and ancillary agreements
Future of Gas Networks – Key issues for debate	Guarantees of origin and other certificates: • Certification • Delegation and determination of bodies responsible for certification across the hydrogen value chain • Definition of the audit mechanisms for certification

Material	Key regulatory aspects covered
Technical and Economic conditions for injecting hydrogen into natural gas networks	<u>R&D and other projects of cross border relevance:</u> • A few existing R&D projects explore the acceptability of hydrogen by gas networks, at not only national but also regional scale
	<u>Other solutions compatible with cross-border trade:</u> • EU wide technical working groups have been formed to address cross border issues
Gas Goes Green Initiative: Delivering the pathway to net zero report	<u>Other solutions compatible with cross-border trade:</u> • Need for more flexible Gas Safety (Management) Regulations (GS(M)R)
The European Gas Infrastructure can help deliver the EU Hydrogen Strategy	<u>R&D and other projects of cross border relevance:</u> • Creation of hubs, notably the N. Sea Wind Power hub in central N. Sea with interconnections to neighboring countries • Establishment of regulatory framework to allow R&D and pilots by infrastructure operators
	<u>Guarantees of origin and other certificates:</u> • Launch of Guarantees of Origin, with a technology-neutral approach and compatible with the EU ETS.
Dutch Government Strategy on Hydrogen	<u>Guarantees of origin and other certificates:</u> • Launch of Guarantees of Origin (Dutch Institue Vertogas already working towards it)
Germany's National Hydrogen Strategy	<u>R&D and other projects of cross border relevance:</u> • A pioneering project is planned to lay the basis for practical work to further develop the national as well as the EU framework to allow for a large-scale roll out of applications for the storage and transport of hydrogen
	<u>Other solutions compatible with cross-border trade:</u> • Call for coordinated support for the development of European regulations, codes and standards in the various fields of application.

Hydrogen Strategy for a climate neutral Europe, in its envisioned 2nd phase of the hydrogen system development, discusses the revision of the Trans-European Networks for Energy (TEN-E) and the review of the internal gas market legislation for competitive decarbonized gas markets. In this context, it suggests the launch of common quality standards, regarding purity of gas etc., or other rules of cross-border relevance. The strategy also suggests repurposing of the existing natural gas infrastructure, to serve the needs for large-scale cross border transport. This is where the TYNDP comes into play, for planning the infrastructural developments needed. Reinforcement of instruments might also be an option in order to secure cross-border coordination. The paper also underpins the need for common standards on an international level, and the EU is already involved in the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), the Missions Innovation and Clean Energy Ministerial Hydrogen initiative (CEM H2I). Focus is given on the common low- carbon threshold/standards, and the Guarantees of Origin system as well as other sustainability certificates which can facilitate EU-wide trading. It is also suggested that the EU's international collaboration could be expanded with the help of international standardization bodies and global technical regulations of the United Nations. Further, in order to eliminate foreign exchange risks, the EU strategy also suggests the development of a structured international hydrogen market in euro.

The Bridge Beyond 2025, identifies cross-border barriers particularly in the Central and Eastern Europe region, due to factors such as lower interconnection capacity levels, the effect of transportation tariffs, and others. Especially when it comes to cross-border tariffs, the paper mentions that some stakeholders have expressed concerns in certain regions, as long-term capacity contracts are coming to an end and bookings shift to a shorter-term horizon. Furthermore, concerns arise because of the way TSOs' assets are valued, indicating that their allowed revenues affect tariff levels, thus posing implications on cross-border trade. To address such issues the paper suggests that along with the implementation of the Tariffs Network Code, the current market design needs to be further addressed in the EU legislation. For instance, the definition of entry-exit system and of harmonized capacity products needs to be further clarified and developed to account for the network topology, flow patterns and the issue of physical congestion. With respect to barriers caused by cross border capacity charges, the paper suggests to allow the reserve price in cross border capacity allocation to be reduced, provided there is agreement between the NRAs, and with the support of ACER as a mediator when needed.

The *NRA Survey on Hydrogen, Biomethane and related network adaptations*, also highlights the issue of cross-border trade in the context of common standards across the EU in terms of H_2 concentration levels at cross-border interconnection points.

The *2050 Roadmap for gas grids*, highlights the European Guarantees of Origin (GO)/certificates system as an important step addressing cross-border barriers. The paper recommends the coordination of cross-border and regional gas quality inventory and with standardization of national and cross-border solutions, where digitalization could potentially play a key role.

The European Hydrogen Backbone mentions the Green Octopus Project (IPCEI), which aims to create a 2000km hydrogen backbone by repurposing existing pipelines, targeting port areas and industrial clusters offering cross-border solutions. The project is based on offshore wind production and the retrofitting of gas infrastructure.

The Public Consultation on Regulatory challenges for a sustainable gas sector focuses on the infrastructure operators and the cross-border impacts, namely the specifications of hydrogen levels that can be injected in natural gas networks that will facilitate cross-border flows of blends of hydrogen and methane. It also addresses issues related to the facilitation of cross-border trading of renewable gas GOs. In terms of the former, the paper suggests that there is a need for an EU framework for decommissioning of infrastructure with a cross-border impact. This could be interpreted, amongst others, as a fair level of cost coverage for maintaining the assets. Regarding the GO system, the paper concludes that in order to have an efficient GO system with tradable GOs across borders, standardization with respect to their function and use and cooperation of the issuing bodies is imperative. Further, to avoid complexity of cross-border trading across the EU, the GO system calls for an EU-wide cooperation system that will account for the conversions between different forms of energy.

Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy, also highlights the need for common gas quality standards to facilitate cross border trade, and the GO system to extend to renewable and low-carbon gases.

The European Commission's report on the impact of the use of the biomethane and hydrogen potential on trans-European infrastructure, also considers the interoperability of gas networks facilitating domestic and cross-border transport of renewable gas, as well as an EU wide guarantees of origin system, as important prerequisites for an efficient decarbonized energy system and market functioning. The recast Renewable Energy Directive extends the guarantees of origin requirements to renewable gases. Further, the European Renewable Gas Registry

(ERGaR) aims to enable cross-border trade and mass balancing of renewable gases, building on voluntary national registries.

The Future of Gas Networks – Key issues for debate (the Oxford Institute for energy studies), identifies a range of important issues, such as standardization, data quality and transparency, verification and certification. Specifically, it first of all raises the question of gas quality, and the wide range of allowed proportions of hydrogen into the gas network between countries. It also discusses the range of terminology of gas types, which have to be eventually standardized, and coupled with systems means whereby gas sources (including imports) can be certified and verified with guarantees of origin. This paper also highlights the issue of who bears the responsibility for certification at the different stages of the value chain (either producers or network operators), and what audit mechanisms will be required. The third issue of cross-border relevance discussed, is the interoperability, which would include gas flows between countries (and within countries), at DSO/TSO level and between two or more networks operating with different gas combinations. Hence, the paper concludes on substantial review and amendment of network codes and ancillary agreements.

The report on *Technical and Economic conditions for injecting hydrogen into natural gas networks (GRTGaz et al., 2019,* explicitly refers to R&D projects related to the acceptability of hydrogen by gas networks, at not only national but also regional scale. The H2-PIMS project in Germany, investigating the compatibility of existing gas transmission infrastructures with CH_4/H_2 mixtures, the H21 Leeds Citygate project, which determines the technical and economic feasibility of converting existing infrastructures in the Leeds metropolitan area to 100% hydrogen, to name a few. Those are some examples of work geared towards identifying the actions to adapt the networks for the transmission of hydrogen in either blended or pure form. European gas operators, however, are also working jointly to develop the hydrogen injection sector through European technical groups, with a view to addressing cross-border issues. Many of them are members of standardization groups carrying out work related to the challenges faced by the sector.

The Gas Goes Green Initiative: Delivering the pathway to net zero report, includes a workstream on gas quality and safety, which considers how the Gas Safety (Management) Regulations (GS(M)R) that currently limits the quantity of hydrogen that can be supplied by the gas system to 0.1% vol. should be changed. The Institute of Gas Engineers and Managers (IGEM) are currently working on changes needed to move quality rules from legislation to a new more flexible industry standard.

The *European Gas Infrastructure can help deliver the EU Hydrogen Strategy (GIE)* report includes a number of projects that can potentially address cross-border issues. Notably, the North Sea Wind Power Hub, by TenneT, Energinet, Gasunie and Port of Rotterdam, which is based on the idea of building one or more hubs in the central North Sea, with interconnections to the bordering countries, where the surplus of electricity produced can be converted to hydrogen for large scale transport or storage. Further, the paper concludes on the creation of a robust regulatory framework that will allow R&D and pilot projects to be developed by infrastructure operators on renewable and low-carbon gases, hydrogen included. In support of creating an EU wide market, the report also refers to the application of green certificates, such as Guarantees of Origin, with a technology-neutral approach and compatible with the EU ETS.

The Dutch Government Strategy on Hydrogen, also refers to the need of establishing a reliable systems of Guarantees of Origin and certification for a hydrogen market. RED II, as stated in the strategy, already provides the framework for a GO system, yet coordination is needed with other European countries to agree on a measurement methodology and implement the EU rules. Vertogas, the Dutch institute responsible for facilitating trade in green gas, will be designated to develop the system. Besides that, the Netherlands, as discussed earlier in this report, the government will consider the network development within the broader North –western European hydrogen market context, to facilitate cross-border flows.

Germany's National Hydrogen Strategy discusses new funding initiatives for research and innovation along the entire hydrogen value chain. Amongst the proposed targeted funding measures, a pro-innovative framework is envisioned to pave the way for the use of hydrogen technologies in real life. In the short-term, a pioneering project is planned to lay the basis for practical work to further develop the national as well as the EU framework to allow for a large-scale roll out of applications for the storage and transport of hydrogen, amongst other and for related business models that are economically viable. This includes the development of quality assurance infrastructure that meets all the security requirements, coupled with an assessment of the systems' and installations' efficiency, and of a billing system that is compliant with calibration law. For this to be realized, any obstacles under the national or EU law will have to be identified along with proposals to address them. In the meantime, to ensure that a market can develop, there is a need to establish reliable sustainability standards and sophisticated quality infrastructure, especially in the field of hydrogen and P2G products. To realize this goal, coordinated support is required for the development of European regulations, codes and standards in the various fields of application. Within this context, Germany intends to intensify the dialogue on common standards with other countries.

5 Hydrogen networks regulatory gap analysis

It is evident that the current regulatory framework of the gas sector will have to evolve in view of H2 market developments. From a technical point of view, the existing natural gas networks need to be upgraded to allow hydrogen injection up to a certain concentration level, but for certain applications there is a need for dedicated hydrogen networks, initially applying at TSO/DSO level. The existing regulation for gas might already cover activities in the context of blending of hydrogen and methane. Nevertheless, for pure hydrogen networks existing regulation, or rather, the absence of regulation, could be an impediment to development. For the purpose of the gap analysis we highlight the differences in the regulatory framework between the two, where needed.

5.1 Gap analysis for injection of hydrogen into the grid

Table 13 summarizes they key findings arisen from the review and meta-analysis of material related to the injection of hydrogen into the grid. The current state and the desired future state, including options to be considered, result from the whole range of papers reviewed and the Consultant's meta-analysis. The following gap analysis does not intend to proritze possible actions, but to list them, so that could be addressed by the hydrogen future market players. Focus areas and the whole content of the following table is not a matter of importance ranking, but a matter of depicting the future of hydrogen energy sector, following the best example of natural gas with a proven success on the European market or other equally successful regulatory models (i.e. regulation on telecommunications.). In no case, a regulated or a non-regulated hydrogen network option is exclusively suggested, but alternative options for both of them are highlighted.

Table 13. Gap analysis

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
The acknowledgement of infrastructure adaptation and new investment costs incurred by the network operators and gas facilities,		Dynamic regulatory approach[23] for H2	• Network planning (DSOs & TSOs cooperation) • Ownership of hydrogen storage facilities – clearer definition of roles (in some EU MS

[23] By the term dynamic regulatory approach, the Consultant refers to a approach based on periodic market monitoring and assessment of the market structure, in order not to prevail an abusing dominant position by hydrogen infrastructure owners.

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
specifically with respect to transmission, storage and liquefied gas facilities	Absence of hydrogen network development planning[21] Inadequate technology specific regulations Uncoordinated infrastructure planning between hydrogen and natural gas/electricity sectors[22]	regulation for the transition phase[24] Clear infrastructure investment plans for hydrogen – coordination with the natural gas and electricity sector Distinction between mixed gas networks and dedicated hydrogen networks[25] Definition of roles amongst TSOs, DSOs, etc. NRAs being aware of infrastructure adaptation and/or new investment costs[26]	ownership unbundled network operators are allowed to own storage facilities) • In case of the identified need for regulation, incentive regulation[27] for network operators and all market participants supporting innovation & R&D. Cost reflectivity should be respected by separate accounting of costs and separate tariffs, thus helping to avoid cross-subsidisation between natural gas and hydrogen. • Support schemes for refurbishment of existing infrastructure and new pipelines, in cases that network owners cannot accomplish it by their own, resulting to high tariffs • NRAs to be aware of investment and adaptation costs under proper consultation

[21] A Hydrogen Strategy for a climate neutral Europe
[22] Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure
[24] The Bridge beyond 2025
[25] Towards the new age of gas networks
[26] NRA Survey on Hydrogen, Biomethane and related network adaptations
[27] By the the term incentive regulation, the Consultant refers to the case that in a regulated hydrogen network, various methods of incentives could be provided, such as Cost-Plus or premium WACC. Cost-Plus might be more sensible for the transitory phase.

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
The time horizon[28] of the regulatory period	Three-phase development plan foreseen in the EU hydrogen strategy[29] No EU harmonised hydrogen blending limits targets and quotas and thus, no harmonized regulation to inject H_2 into the existing grid[30]	Development of infrastructure by specific target years (2030, 2050) to realize decarbonization goals in parallel with market development[31]	• Clear regulatory phases and milestones, in cases of regulated hydrogen networks • Assessment of infrastructure needs for mixed gas networks (transition phase) and dedicated hydrogen networks) • Set specific H_2 blending quotas by specific target years, eventually leading to harmonization of regulation across the EU • Regulatory sandboxes at EU level with the supervision of NRAs at national level to develop R&D and pilots in the medium term (in order to avoid price and access discrimination and help to set an investment framework that attracts networks operators) • Planning and regulation of medium-range backbone transmission infrastructure
The benefits expected from the adaptations in developing a hydrogen network	Current methods applied, e.g. CBA[32]	Optimal investment decisions with respect to infrastructure development[33]	• Introduction of a Hydrogen Network Code and Network Tariff Regulation, at least blending hydrogen, in case of regulated hydrogen networks with a clear regulation on revenues and tariffs

28 Time horizon may also include other aspects of time, e.g. depreciation period.
29 Hydrogen Strategy for a climate neutral Europe
30 NRA Survey on Hydrogen, Biomethane and related network adaptations
31 Hydrogen generation in Europe, Overview of costs and key benefits
32 The Bridge beyond 2025

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
	Inhomogeneity in CBA methodologies or other appraisal method used[33]	Regulatory framework to address the benefits, apart from the risks[34]	methodology at EU level[35], by also making certain that hydrogen is not included in the natural gas revenue and tariff regulation, in order to avoid cross-subsidisation for hydrogen by natural gas users • ACER to be authorized to issue binding CBA guidelines • Sustainability benefits to be factored in CBA and full assessment of decarbonization effects to be considered in decommissioning and repurposing of infrastructure • PCIs (CBA appraisal) to include hydrogen projects
Market, economic and financial terms and conditions to be accounted by regulators for hydrogen	Lack of framework (particularly for dedicated hydrogen networks):	Effective competition in the market, with high levels of liquidity[37]	• Clear framework for licensing of hydrogen facilities • Clear role of NRAs regarding hydrogen • Monitoring of hydrogen production facilities and hydrogen production, in terms of volumes and other paraeters

33 Public Consultation on Regulatory challenges for a sustainable gas sector
34 Hydrogen Europe Vision on the role of hydrogen and gas infrastructure on the road toward a climate neutral economy
35 The existing gap between the current applied methods (e.g. CBAs/inhomogeneity) and the desired future state of optimal investment decisions could be covered by a Hydrogen Network Code and Network Tariff Regulation, following the best example of natural gas with a proven success on the European market, but making sure hydrogen is treated separate from natural gas
37 CEER Consultation paper on the regulatory challenges for a sustainable gas sector

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
	• Licensing and registration issues (lack of provisions for dedicated hydrogen networks • Unclear P2G legal status • Unclear future role of TSOs Institutional and structural issues[36]	Sustainable and transparent market[38]	• Participation of hydrogen producers in balancing, maybe in a more distant future • Storage and LinepackRegulation • Revision of gas market legislation • The unbundling of TSOs/DSOs must be respected. Provisions for TSOs/DSOs to invest in projects such as P2G until market mature enough.If no interest is expressed by market parties/investors, TSOs/DSOs should be generally avoided, even in cases of insufficient interest in P2G investment by market participants. However, careful assessment must be made for pilot projects and other exceptional circumstances where an investment could be carried out by TSOs/DSOs and under close supervision of NRAs.
New technologies and products with a focus on those who address cross border barriers, for hydrogen handling	Immaturity of relevant technologies Some projects already address cross-border	Single European market with unhindered flows and interconnections[39] Prospects for unified hydrogen market[39]	• Definition of hydrogen and hydrogen facilities, as well as clear definitions for renewable and low carbon gases • Hydrogen standards (including Safety standards for hydrogen and blending limits, gas quality measurements)

[36] The Bridge beyond 2025
[38] Hydrogen Strategy for a climate neutral Europe

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
	barriers, creating a hydrogen backbone[39] Lack of common gas quality standards at large[40] Low interconnection capacity level in certain areas[40]		• EU-wide Guarantees of Origi n (GO)/certificates system (addressing cross-border barriers) • Fuel Mix disclosure obligations on suppliers

5.2 Key findings and recommendations

This section aims at providing recommendations for creating a framework that supports and enhances the uptake of clean hydrogen, while promoting its role as a facilitator of sectoral integration. The recommendations refer to both mixed gas networks and dedicated hydrogen networks, yet where necessary distinctions are made.

Definitions and clarity

Initially, there is a need for clear definitions for renewable and low carbon gases. The recast Renewable Energy Directive includes a taxonomy of hydrogen, yet it focuses on the transport sector and not on the use of hydrogen in other important sectors, e.g. industry. Clarity is required also on the legal status of energy storage in particular with respect to power-to-gas (P2G). Under the current Electricity Market Design Directive, P2G is likely restricted to the function of storing energy. Nevertheless, in practice, P2G could become an important part of, amongst others, a hybrid energy system. Therefore, its definition should not be limited to its role as energy storage from an electricity market perspective. This has also implications on the applicability of the unbundling. In response to this, a test framework could be applied allowing TSOs to invest in such facilities, until the market is mature enough to attract more players. The term of immature market refers to the case that no interest is expressed

[39] Hydrogen Strategy for a climate neutral Europe
[40] NRA Survey on Hydrogen, Biomethane and related network adaptations

by market parties/investors and as a result TSOs/DSOs could be allowed to proceed in such investments. In such cases, market failure needs to be detected and investment to be carried out under close supervision of NRAs.

Extension of the Guarantees of Origin scheme

An important aspect discussed in most of the papers reviewed, is the extension of the Guarantees of Origin scheme to cover renewable and low carbon gases, as well as pure hydrogen. This would not only be a means of proving the origin of energy to end-users, but it would also help address cross-border barriers. The recast EU Renewable Energy Directive (2018/2001/EU) extends the scope of GOs to cover hydrogen and mandates European Standard Organizations to review the standard EN 16325, which specifies the requirements for Guarantees of Origin. This standard currently only covers electricity, yet CEN and CENELEC are updating it to extend it to hydrogen as well, amongst other energy carriers. A transparent framework accounting for the GOs for hydrogen could be provided. To this end, there is a need of coordination between countries to agree on a common methodology for tracing and certifying hydrogen production. This should apply to both renewable and non-renewable low carbon hydrogen.

Harmonized regulation and guidelines

Currently, the allowed concentration of hydrogen in the gas grid, if allowed, varies amongst member states. The current absence of harmonized regulation, which would have taken into account all technical restrictions of all networks within its scope, is a major constraint for the development of cross-border flows. Thus, to avoid fragmentation of the gas market, common gas quality standards should be agreed upon and adopted by Member States.

The EU Hydrogen Strategy foresees investments of 65 billion euros until 2030 for hydrogen transport, distribution and storage, and hydrogen refueling stations. For financing and operation specific to network operators, there is a need of infrastructure planning, taking into account input provided bythe TYNDPs. These could be changed to accommodate the planning of robust infrastructure for hydrogen. To that end, ACER could launch binding guidelines for the development of TYNDPs regulation or NRAs and ACER could be responsible for assessing and/or approving the TYNDP, the scenarios included as well as the Cost Benefit Analysis (CBA) methodology used to evaluate the investments. At this point, it should be stressed that, following the time planning of the EU Hydrogen Strategy, an assessment of infrastructure needs for mixed and dedicated hydrogen networks should be conducted, for the medium- and long-term. Further, to test and roll out new technologies, regulatory sandboxes could be deployed, under the supervision of NRAs at national level and ACER at EU level. The sandboxes could also serve as a means to ensure revenue certainty for innovation actions by TSOs. Under the current regime, there is a certain degree of certainty, yet, this should be also ensured for the next regulatory period to account for hydrogen projects as well. Within the same spirit, the TEN-E regulation could also lead as a driver, to regulatory provisions for cost recovery of investment and operations for hydrogen. New projects, particularly those targeting 100% hydrogen in the networks, should be able to apply for PCIs, as it may be included in the revised TEN-E guidelines, applicable only as from 2022 most likely.

Efficient hydrogen market and network infrastructure

Another array of issues that need to be addressed in order to set the scene for an efficient hydrogen market and specifically with respect to network infrastructure, includes apart from the unbundling discussed above, the tariffs, third party access and market regulation. To that end, direct and transparent market-based mechanisms and regulatory oversight to allow for a non-discriminatory access to infrastructure are prerequisites. Important tools for the energy regulators are network rules and sufficient monitoring to allow them to intervene with policy measures where needed. In terms of tariffs, under the current regime, revenues by network users might as well be used to finance mixed gas networks on the condition that the investments are deemed necessary. This, however, is not the case for dedicated hydrogen networks, and this should be accounted for in a new framework to allow for dedicated financing of network types that are currently not regulated. A hydrogen market design, in line with the electricity and gas markets, incorporating all those elements would help realize the full potential of hydrogen towards decarbonization.