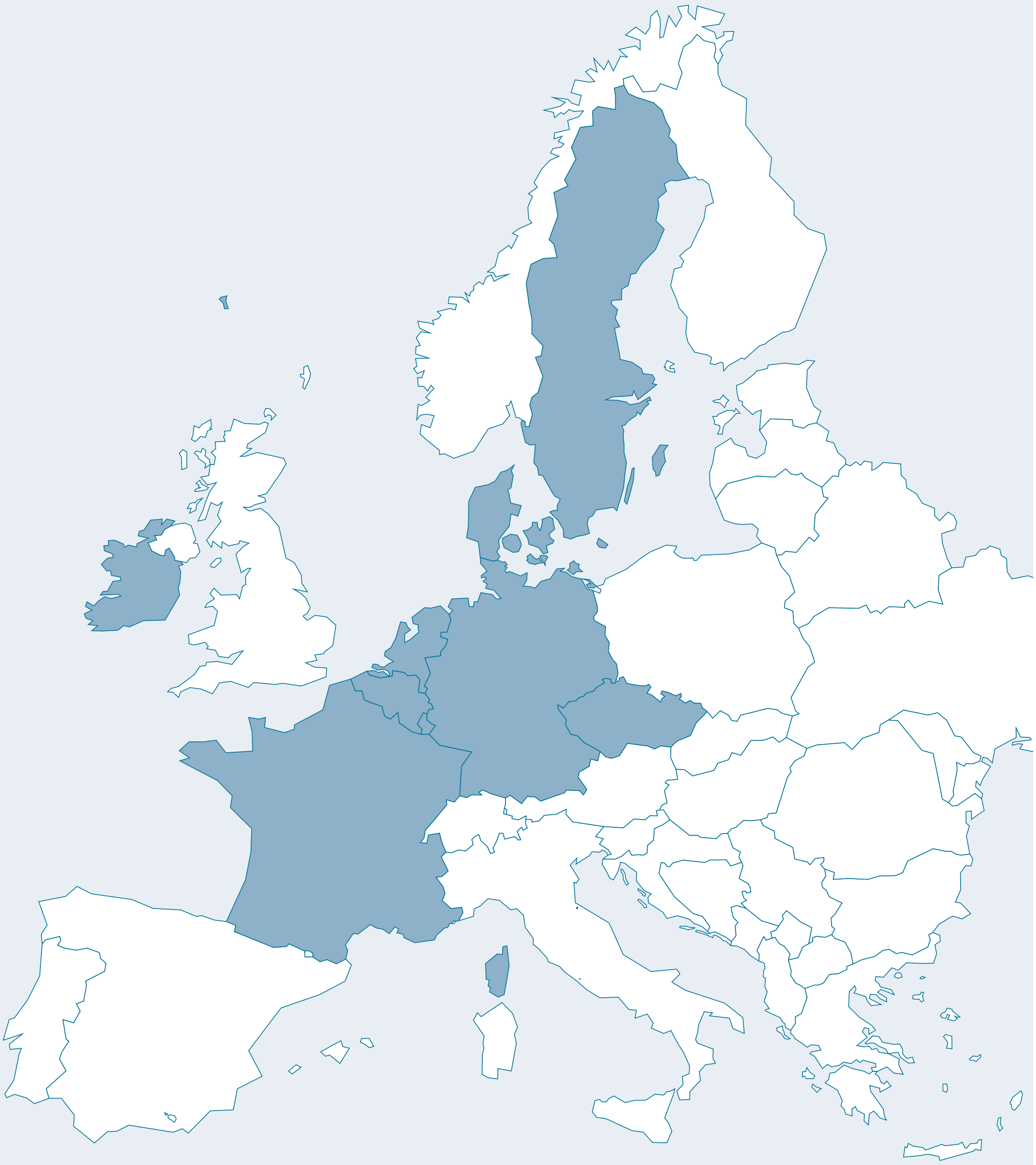
GAS REGIONAL INVESTMENT PLAN NORTH WEST REGION

5TH EDITION – 2022

NORTH WEST REGION

Cover picture courtesy of Gasunie



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FOREWORD

It is our pleasure to welcome you to the fifth edition of the North West Gas Regional Investment Plan (NW GRIP). The NW GRIP is the result of a close cooperation between Transmission System Operators (TSOs) of the nine European countries from the North West GRIP Region (NW Region). The European NW Region covers Belgium, Denmark, France, Germany, Ireland, Luxembourg, Sweden, The Netherlands and the Czech Republic.

The 2022 edition of the NW GRIP builds on previous editions and complements the ENTSOG Ten-Year Network Development Plan 2022, which after a delay is expected to be published in 2023.

This edition of the NW GRIP focuses on several key challenges for the region:

- The gaining momentum of the energy transition and the role of gas infrastructure in developing a sustainable energy system and society for Europe.
- Security of gas and energy supplies has received significant focus in recent months, following the war in Ukraine. Due to recent events this report also includes a chapter outlining the security of supply developments in the NW GRIP region.
- The switch from low calorific gas (L-gas) to high calorific gas (H-gas) in the NW Region with associated conversion infrastructure projects.

The coordination of this document has been facilitated by Fluxys and Gasunie Transport Services (GTS). The participating NW GRIP TSOs (Fluxys, Gasunie Transport Services B.V. [GTS], Open Grid Europe GmbH [OGE], Thyssengas GmbH [Thyssengas], Gascade Gastransport GmbH [Gascade], ONTRAS Gastransport GmbH [ONTRAS], Gasunie Deutschland Transport Services GmbH [Gasunie Deutschland], Creos Luxembourg, GRTgaz, Energinet, Gas Networks Ireland [GNI], Swedegas, NET4GAS) welcomes feedback from stakeholders to improve future editions of the report.

We hope that you will enjoy reading the NW GRIP and that this report will contribute to the further development of the (North West) European gas system.

Pascal De Buck

Managing Director & CEO, Fluxys

Bart Jan Hoevers

CEO of GTS and member of the Executive Board of Gasunie

EXECUTIVE SUMMARY

The 5th NW GRIP contributes to the fulfilment of tasks listed in the European Directive 2009/73/EC Article 7 and Regulation 715/2009 Article 12.

The first chapter of the report covers the developments in the countries in the NW Region relating to the energy transition. The developments described are predominantly focused on a ten-year timeline, ranging from 2022 up to 2032. This section respectively covers developments in natural gas demand, biomethane and hydrogen (H_2). Additionally, the first chapter covers recent concerns around natural gas security of supply and actions that have already been undertaken to ensure security of supply in the NW Region. Finally, the first chapter provides an overview of projects and initiatives that gas TSOs are involved in which facilitate the decarbonisation of gas infrastructure across North West Europe.

Generally, the NW Region is expected to see a gradual phase out of natural gas in the future[1]. For the coming ten years, most countries would see either a decrease or a relatively stable trend in natural gas demand. In part the decline would be caused by an increase in the usage of carbon-neutral and low-carbon alternatives such as biomethane and hydrogen.

Over the past couple of years, the production of biomethane has been increasing in North West Europe. The overall trend is that the production and share of grid injected biomethane would further increase towards 2030 with new national and European Union (EU) energy policies being implemented. Recently the European Commission (EC) has set a new target for biomethane in the REPowerEU Plan[2] as one of the measures to reduce the dependency on foreign fossil fuels. The European Commission sees a potential of 35 billion cubic meters (bcm) of biomethane production in 2030. This equates to around 350 Terawatt-hours (TWh) which indicates that biomethane would play a stronger role in the future energy mix of the different Member States.

The demand for hydrogen is expected to grow rapidly towards 2030 and 2050 in all countries. It is expected to penetrate first in the industry and the transport sectors in most Member States. At a European level, the EC has increased its ambitions for hydrogen within the REPowerEU plan, setting a target of 20 Megatonnes (Mt), equivalent to 666 TWh,

1 The projected evolution for natural gas demand is based on pre-energy crisis studies. The impact of high energy prices on the evolution of the natural gas demand is not taken into account in this report.

2 European Commission 2022 – REPowerEU Plan

yearly consumption of hydrogen by 2030. The European Commission estimates that half of the 20 Mt will be produced domestically within the EU and the other half will be imported from outside the EU.

Security of gas and energy supplies have received significant focus in recent months following the war in Ukraine. Gas flows from Eastern to Western Europe have been reversed and alternative supply routes are being optimised to enhance security of supply in Europe. These new supply routes and flows from West to East (e.g. LNG from new floating storage regasification units (FSRUs) and the recently commissioned Baltic Pipe) are expected to remain in place and even increase for the coming years.

Furthermore, the first chapter provides an overview of projects and initiatives that gas TSOs are involved in to facilitate the decarbonisation of gas infrastructure across NW Region. These initiatives demonstrate the commitment of TSOs to actively engage in the decarbonisation of the gas and the energy system as a whole. When looking at the different decarbonisation projects, it is evident that the technologies adopted vary across Member States, which largely reflects the differing focuses, strengths and priorities of national policies.

The second chapter of this report is focused on the L-gas markets in the NW Region. The decline of L-gas production is causing a pressing investment requirement. As the only region where L-gas is produced and consumed, the phasing out of the Groningen field and the decline of German L-gas production requires considerable infrastructure investments, which are already well underway, to allow L-to-H market conversion in large parts of Belgium, France and Germany. A detailed overview is presented on the current status of the L-gas markets and the ongoing associated infrastructure adaptations that are required for a successful market conversion and integration into the H-gas system.


Picture courtesy of Fluxys

A ENERGY TRANSITION TOWARDS A SUSTAINABLE FUTURE

This chapter aims to highlight the contribution of its member TSOs towards a sustainable and secure energy transition and decarbonisation in the NW Region. In the first section, the role of gas infrastructure towards a net zero society is highlighted. Due to the recent energy crisis in Europe, this section also includes details regarding security of gas supply in the region. In the second section, specific energy transition projects will be presented per country.

1 THE ROLE OF THE GAS INFRASTRUCTURE TOWARDS A SECURE NET ZERO SOCIETY

The NW Region is undergoing a rapid energy transition towards a net zero society by 2050 with ambitious energy and climate goals set by governments in the NW Region and the EU. The gas system is a key enabler to achieving these goals and TSOs in NW Region are committed to ensuring that gas infrastructure can play its role in decarbonising the energy system. TSOs in the NW Region are actively working to enable the injection and transportation of renewable and low-carbon energy carriers such as biomethane and hydrogen through their networks.

While working to tackle the climate crisis, the global energy market has experienced significant disruption caused by the war in Ukraine. As a result, the EC has presented its REPowerEU Plan, which aims to accelerate the renewable energy transition and end the EU's dependency on Russian fossil fuels. Amongst other things, this plan will have a significant impact on the development of gas consumption and the production of renewable gases in the NW Region. More than ever, it is important that the TSOs in the NW Region ensure that their infrastructure plays a key role in enabling decarbonisation and reducing dependency on Russian fossil fuels.

The aim of this section is to provide an understanding of the overall trend of developments occurring across the countries in the NW Region. In reality, these developments towards a decarbonised gas system occur at different stages with different approaches across the Member States. The developments described in the next sections focus predominantly on a ten-year timeline towards 2032 with some longer-term perspectives towards 2050. Firstly, the evolution of natural gas demand is discussed per country[3]. The evolution of natural gas demand is an important development directly linked to the evolution of renewable, as part of the natural gas demand is expected to be substituted by carbon-neutral and low-carbon alternatives. Secondly, the increasing production of biomethane to replace natural gas is discussed per country. Thirdly, hydrogen developments and evolution are described at a European level. Finally, the last section summarises the recent concerns around natural gas security of supply and actions that have already been undertaken to enhance this at a European level.

3 The impact of the high energy prices of 2022 on the demand projections for natural gas is not taken into account in this report.

Picture courtesy of Fluxys

1.1 EVOLUTION OF NATURAL GAS DEMAND

Across the NW Region, there is anticipated to be a decrease or stabilisation of natural gas demand in the coming ten years. However, the situation differs from country to country, with some countries in the region foreseeing a slight increase in natural gas demand rather than decrease. These differences are mainly centered on the evolution of natural gas demand for specific sectors within those Member States.

In the Netherlands, natural gas demand overall is expected to decline. Most of the reduction is foreseen in power plants and combined heat and power (CHP). This is mainly caused by the increased capacity of solar photovoltaic (PV) and wind generation. However, the foreseen closure of all coal fired power plants could result in an increase in the usage of gas fired power plants.

A similar situation is expected to occur in Denmark where an increase in gas consumption for process industry is expected up to 2025 due to the shift from coal to gas, although the current situation with high natural gas prices may slow this shift. The gas consumption for heat and power production is expected to decrease as it transitions from use in base load to peak load management with increasing solar and wind power. Gas consumption for household and district heating is expected to decrease significantly as Danish political ambitions seek to minimise this use. Additionally to the reduction of gas demand, natural gas is being replaced with biomethane.

In a historical context Sweden has only had a very limited gas production. As a result, the forecast for the Swedish gas demand has been equal to the need of importing gas to Sweden from the Danish gas infrastructure. According to estimates of Energinet and the Swedish Energy Authorities, the overall gas demand is expected to decrease in both the mid- and long-term basis, which is a consequence of a declining demand in most sectors. Still, increased use of LNG in the Swedish industry is expected to make up for some of the losses in other sectors. As a part of the long-term development plan in Sweden, natural gas is to be replaced by biomethane and hydrogen, hence the share of use of both gases would increase significantly.

For the upcoming years Germany is expecting a downward trend in natural gas demand in all sectors. The natural gas demand would be increasingly satisfied by renewable gases, like synthetical methane or hydrogen. In Belgium the natural gas demand is expected to remain relatively constant up to 2030. In Luxembourg the natural gas demand is expected to slightly decrease towards 2030. However, beyond 2030 both countries expect a decrease of natural gas demand.

For France the National Low Carbon Strategy[4] enacted in national legislation has set the target of carbon neutrality by 2050. To achieve this objective, natural gas demand is expected to further decrease over the coming years. The multi annual Energy Program adopted in 2020 foresees a 22 % reduction of natural gas primary consumption by 2028 compared to 2012. Gas demand is predicted to decrease in all scenarios, in all sectors (residential & industry) except for mobility, while natural gas would be progressively replaced by biomethane (reaching at least 10 % of gas demand by 2030).

4 https://www.ecologie.gouv.fr/sites/default/files/en_SNBC-2_complete.pdf

For Ireland, natural gas demand is expected to decrease by 12 % in the coming ten years. The main driver for this decrease is a forecast contraction in the power generation sector due to increased electrical interconnection with the UK and Europe, and the forecast build out of renewable generation towards the end of the period. This is despite the replacement of a number of conventional fuel generators (coal, peat) with new gas fired generation and a predicted 42 % increase in electricity demand, significantly driven by increased demand for data centre connections and electrification of heat and transport. Energy efficiency measures and conversions of gas boilers to heat pumps are forecast to reduce residential sector demand. The industrial and commercial sector is forecasting growth despite increased energy efficiency measures, driven primarily by connections from contracted large commercial users such as data centres. Ireland has a target to achieve 80 % of its electricity by 2030 from renewables. However, given demand increases and planning lead-times, it is envisioned that much of this target will be delivered in the later stages of the decade and into the next decade with conventional gas fired generation required in the interim to ensure system adequacy.

An increase in natural gas demand can be observed in the Czech Republic over the next ten years. The increase in natural gas demand would be mainly caused by the shift away from coal combustion in industry and heating towards gas. Another predicted reason would be the increasing consumption of gas for electricity generation.

Generally, the NW Region expects to see a gradual phase out of natural gas in the future. For the coming ten years most countries would see either a decrease or a relatively stable trend in natural gas demand. In part, this decline would be caused by an increase in the usage of renewables such as biomethane and hydrogen. The next sections will focus in on the biomethane and hydrogen developments across the NW GRIP countries.

1.2 EVOLUTION OF BIOMETHANE DEVELOPMENTS

In a net zero society biomethane supports the decarbonisation of the gas systems and the consumer segments which have lesser options for electrification like heavy industry and transportation while also supporting the balance of a power system with increasing levels of intermittent renewable energy.

Over the past couple of years, the production of biomethane has been increasing in NW Region. The overall trend is that the production and share of grid injected biomethane would further increase towards 2030 with new national and EU energy policies being implemented. Recently the EC has set a new target for biomethane in the REPowerEU Plan as one of the measures to reduce the dependency on foreign sources of natural gas. The EC sees a potential of 35 bcm of biomethane production in 2030, corresponding to approximately 350 TWh, which indicates that biomethane would play a stronger role in the future energy mix of the different Member States.

Denmark has since 2013 been increasing levels of grid injected biomethane, with an expected share of 30 % by 2022. With a new national energy policy[5], it is expected that Denmark can achieve a 100 % share of renewable biomethane by 2030 or earlier. Accounting for existing, planned and potential biomethane production facilities, the supply of biomethane could reach between 12.5 to 18 TWh in 2030.

Biomethane production has been in strong expansion for the last decade in France, doubling every year and reaching 6.4 TWh of production capacity in 2021 from 365 injection facilities. In 2030, biomethane production is estimated to reach between 30 and 54 TWh. These figures are putting the biomethane sector already above national targets for 2023 and 2030 (renewable gas comprising 10 % of gas consumption in 2030). The potential for biomethane that can be injected into the gas network has been estimated to 130 TWh by 2050. The theoretical potential has been estimated to 430 TWh, of which gas network operators have estimated that 320 TWh can be produced and injected into the French gas network[6].

The Czech Republic is anticipated to produce between 3.7 to 4.8 TWh by 2030. The current level of biomethane production is around 0.12 TWh, but it is expected that roughly 223 new biomethane production facilities could be connected over the next ten years.

Likewise, the production of biomethane is expected to increase in Belgium and Germany in the mid to long run. Depending on willingness and public support, the biomethane production in Belgium could range between 2 to 10 TWh by 2030, while in Germany the expectation is c. 74 TWh by 2035 and c. 88 TWh in 2045[7].

5 https://www.regeringen.dk/media/11470/klimaaftale-om-groen-stroem-og-varme.pdf
6 "A 100 % renewable gas mix in 2050?" – ADEME in 2018
7 Figures taken from Dena study "Leitstudie Aufbruch Klimaneutralität". Figures have been converted from heating to calorific values taken 1.1.

Picture courtesy of ONTRAS

Ireland targets a biomethane production of 5.7 TWh by 2030[8] which would see biomethane deliver 10 % of the methane demand. Furthermore, Ireland has a large agricultural export industry which indicates a potential for producing biomethane at scale.

The Dutch government has set a national target for 18 TWh of biomethane production by 2030. In the most optimistic scenario the biomethane production could reach 26 TWh (or even more), which accounts for about 10 % of the Dutch methane demand in 2030.

Sweden has set a target of reaching a 10 TWh national production of biomethane by 2030. With the current production of 3.2 TWh in 2021 a total growth of more than 312 % from 2020 to 2030 is planned. However, the Swedish biomethane industry has launched a proposal with a specific target of 15 TWh by 2030.

However, a country like Luxembourg has limited potential for domestic biomethane production. Therefore, Luxembourg does not focus on large increases in biomethane production.

8 https://www.gov.ie/en/press-release/dab6d-government-announces-sectoral-emissions-ceilings-setting-ireland-on-a-pathway-to-turn-the-tide-on-climate-change/

1.3 EVOLUTION OF HYDROGEN DEVELOPMENTS

Hydrogen is one of the key building blocks for the transition towards a net zero society in 2050, required to enable decarbonisation in hard to electrify sectors and to integrate more renewables into the system. Hydrogen can help the future power systems to become more resilient through sector coupling between electricity and gas systems, delivering both the short and long term flexibility needed to operate an energy system with increasing intermittent renewables.

Today in Europe between 5.8 Mt[9] (193 TWh) and 6.3 Mt[10] (210 TWh) of hydrogen is already consumed each year, mostly in the industrial sector. Most of the hydrogen produced today in Europe is based on steam methane reforming (i.e. natural gas cracking) or obtained as a by-product from steel or petrochemical processes[11] (i.e. fossil fuels cracking) and as such, involves a significant carbon footprint.

The demand for green and low-carbon hydrogen is expected to grow rapidly towards 2030 and 2050 in all countries due to decarbonisation efforts towards the European aim of a net zero society by 2050. It is expected to penetrate first the industry and the transport sectors. In the industry sector, it is expected to be used to replace fossil feedstock or fuels for process heating. In the transport sector, hydrogen is expected to be first used as a fuel for long distance transport as for road freight trucks (i.e. fuel cell electric vehicle) or as hydrogen based fuels for aviation (i.e. sustainable aviation fuels) and shipping (e.g. methanol, ammonia, …). After 2030, hydrogen could penetrate space heating for the building sector (e.g. to replace natural gas) and the power sector with new generations of hydrogen gas power plants.

At a European level, the Commission is targeting 20 Mt (666 TWh) of hydrogen consumption in Europe by 2030. This target has been defined within the REPowerEU Plan helping to phase out Russian fossil fuels well before 2030. The EC estimates that half of the 20 Mt will be produced domestically within the EU and the other half will be imported to Europe.

To supply this increasing demand, additional hydrogen imports and production capacities will be required. In both the Fit-for-55 package[12] and the REPowerEU Plan, the EC focuses on the production and the import of renewable/green hydrogen. Therefore, the EC plans a total European electrolyser capacity growing from 17.5 GW by 2025 to 40 GW by 2030[13]. The production of hydrogen will evolve with the CO_2 emission reduction targets, from current CO_2 intensive hydrogen productions to low carbon or green hydrogen productions (e.g. H_2 from electrolysis, steam methane reforming + carbon capture and storage, etc.)

In parallel to those European ambitions, almost all Member States have built their own hydrogen strategy, introducing at the same time their national ambitions in terms of hydrogen development, demand, imports, production capacities, transport and storage infrastructures. More details on national hydrogen developments can be found in the energy transition projects section (chapter 2).

To make it concrete, a group of 11 European TSOs published in 2020 a proposal of how a dedicated European Hydrogen Backbone (EHB) can develop over the time to connect regions with high supply potential with the different hydrogen demand regions in Europe based on mainly repurposed natural gas pipelines. Since then, the EHB group has been enlarged and today 31 TSOs from 28 countries are participating in this initiative (i.e. 25 EU Member States + United Kingdom + Norway + Switzerland). In the latest EHB reports 2022[14, 15], the EHB initiative answers the European hydrogen ambitions by proposing a European hydrogen infrastructure for 2030 and 2040. This proposition is aligned with the latest announcement from the REPowerEU Plan regarding hydrogen development.

The EHB initiative proposes a gradual approach by building a dedicated hydrogen infrastructure in different phases. In a first phase towards 2030, five supply and import corridors[16] connecting initially industrial clusters, ports, storages, and hydrogen valleys to regions of abundant supply before expanding and connecting Europe with neighbouring regions with export potential.

9 Irena 2022 – Hydrogen consumption in 2020 – Geopoplitics of the Energy Transformation, P 25
10 IEA 2021 – Hydrogen in North-Western Europe – A vision towards 2030 – P 18
11 IEA 2021 – Hydrogen in North-Western Europe – A vision towards 2030 – P 18
12 European Commission 2021 – Green deal proposal
13 European Commission 2022 – REPowerEU Plan
14 European Hydrogen Backbone 2022 – "Five hydrogen supply corridors for Europe in 2030"
15 European Hydrogen Backbone 2022 – "A European hydrogen infrastructure vision covering 28 countries"
16 European Hydrogen Backbone 2022 – "Five hydrogen supply corridors for Europe in 2030"

Those five corridors span across both domestic and import supply markets (consistent with the three import corridors identified by the REPowerEU Plan) are represented in Figure 1.

This would lead in 2030 to already 28,000 km of hydrogen infrastructure. This hydrogen infrastructure would be composed of mainly repurposed natural gas infrastructure and where needed with new hydrogen infrastructure parts.

In a second phase between 2030 and 2040, the EHB would continue to grow, covering more regions and developing new interconnections across Member States[17] and to adjacent neighbour countries. More information on the EHB initiative and plans are available here.

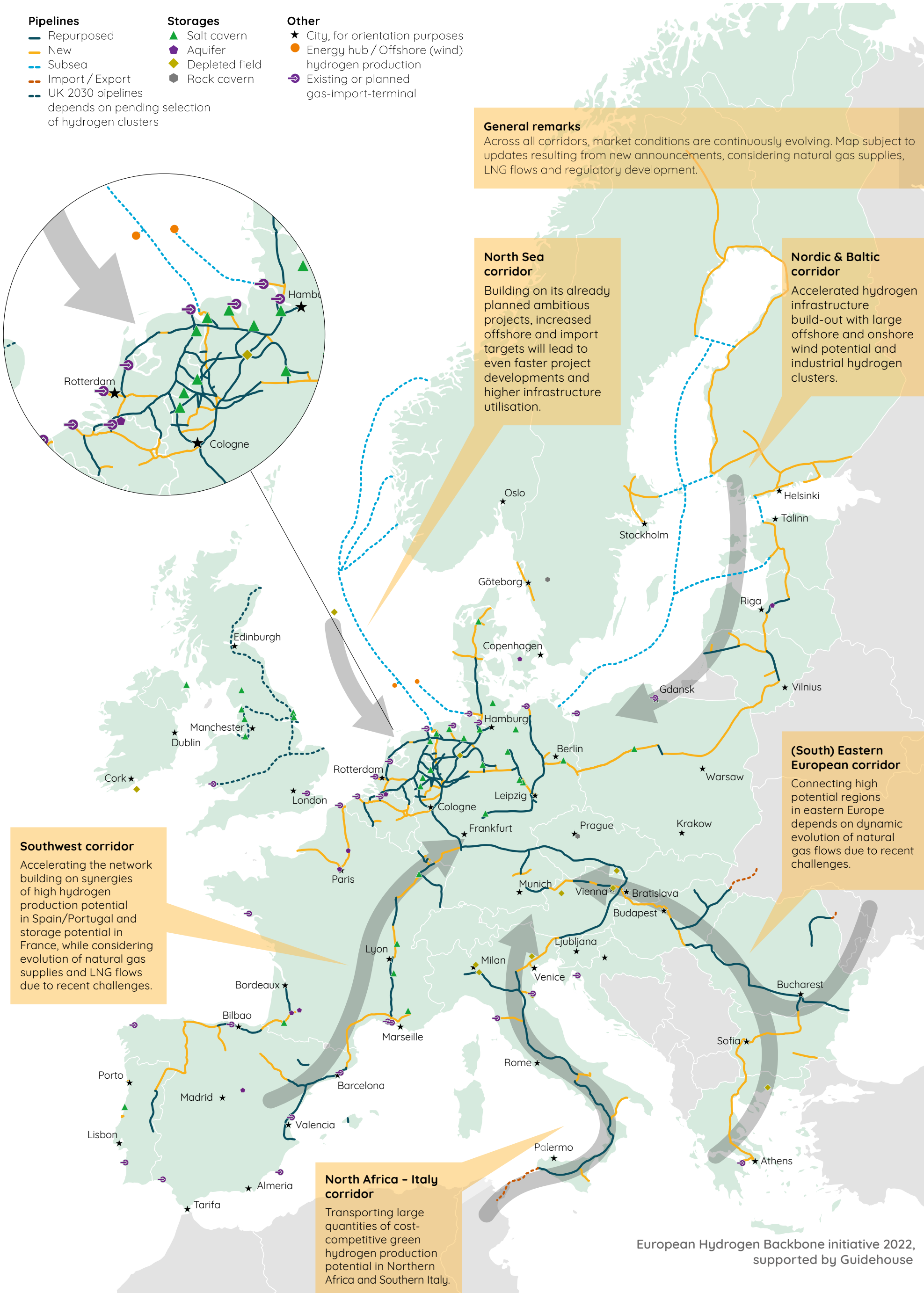


Figure 1: 2030 EHB network map (aligned with REPowerEU ambitions)

17 European Hydrogen Backbone 2022 – "A European hydrogen infrastructure vision covering 28 countries"

Picture: istockphoto.com

For this infrastructure to be built large investments will be required. The EC[18] estimates a total investment for key hydrogen infrastructure in the range of € 28–38 billion for EU internal pipelines and € 6–11 billion for storage by 2030.

The EHB initiative expects that the proposed European Hydrogen Backbone with the emerging corridors in 2030 will continue to grow between 2030 and 2040, covering more regions and developing new interconnections across Member States. A core EHB can be envisaged by 2040, as large supply corridors come together. The EHB initiative[19] estimates a total investment between 80–143 billion € for a mature European hydrogen infrastructure towards all directions proposed in 2040.

To achieve the REPowerEU Plan targets by 2030, the EC will:

- Also map preliminary hydrogen infrastructure needs by March 2023 in a collaborative process with Member States, national regulatory authorities, ACER, ENTSOG, project promoters and other stakeholders;
- Mobilise EU funding;
- Set up dedicated work stream around hydrogen.

For those developments to happen, some main regulatory barriers need to be overcome. Such as:

- The lack of explicit regulatory framework for H_2 transportation;
- The unclarity for gas TSOs on ownership, operation and financing of H_2 infrastructure;
- The regulatory recognition of cost for repurposing, retrofitting, and gas quality management.

Resolutions to these barriers have been proposed by the EC as part of the revision of the Hydrogen and decarbonised gas market package[20] published in December 2021 which is currently under review by the EU institutions and likely to be enacted into legislation by mid-2023.

18 European Commission 2022 – REPowerEU Plan – SWD – https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022 %3A230 %3AFIN&qid=1653033922121
19 European Hydrogen Backbone 2022 – "A European hydrogen infrastructure vision covering 28 countries"
20 Hydrogen and decarbonised gas market package https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/hydrogen-and-decarbonised-gas-market-package_en

1.4 SECURITY OF SUPPLY

Security of gas and energy supplies have received significant focus in recent months, following the war in Ukraine. Gas flows from East to West have been reversed and alternative supply routes are being optimised to enhance security of gas supply in Europe. These new supply routes and flows from West to East (e.g. LNG from new floating storage regasification units (FSRUs) and the recently commissioned Baltic Pipe) are expected to remain and even increase in the coming years.

On a European level, the EC and Member States plan to phase out Russian fossil fuels by 2027. In order to reduce its dependence on Russian fossil fuels, the EC put in place its REPowerEU Plan focusing on energy savings, diversification of energy supplies (e.g. new LNG terminals, new pipelines, removal of existing capacity bottlenecks etc.), and an accelerated roll-out of renewable energies.

To achieve this, current gas infrastructures are being optimised (e. g. network optimisation, LNG terminal optimisation, minimum filling targets for gas storages and solidarity arrangements are being agreed between neighboring countries). However, the current interconnection and import capacities remain insufficient to allow the complete phase out of Russian gas, despite the already high interconnectivity of the European gas grid. Structural infrastructure reinforcements as well as new biomethane and LNG installations are required to enhance diversity and better ensure security of supply in Europe. Additionally, the integration of green and low-carbon hydrogen throughout the EU is necessary to achieve the objectives of the REPowerEU Plan. These infrastructure reinforcement needs are currently being studied and reviewed by TSOs across Europe.

An example of recent developments in security of supply in the NW Region alone is the planned commissioning of several FSRUs to increase the regasification capacity of the region. New land-based LNG terminals are also being constructed over the coming years. Additionally, the regasification capacity of several existing land-based LNG terminals will be expanded[21]. All these developments will allow the import of more LNG into the region, in turn decreasing dependency on Russian gas.

21 https://www.gie.eu/transparency/databases/lng-database/

Picture courtesy of EemsEnergyTerminal

2 ENERGY TRANSITION PROJECTS

The following section provides a selected overview of the planned and ongoing infrastructure projects that are aimed at supporting the rapid energy transition in the NW Region towards a net zero society. TSOs in the region are focused on energy transition projects that provide a cost-efficient pathway to decarbonisation, whilst also maintaining a high level of security of supply.

2.1 BELGIUM

2.1.1 Improving security of supply while ensuring energy transition

In the context of the changing gas flow patterns seen in 2022 in the NW Region (West to East), new infrastructure projects improving the security of supply from both a Belgian and European perspective are currently being studied. These new pipeline projects (designed to be hydrogen ready) will allow significantly higher quantities of gas to flow from the West (Zeebrugge area) to the East.

2.1.2 Creating infrastructure for the future

Fluxys is ready to build the gas network of the future with plans to progressively transform and develop the high-pressure natural gas network in Belgium into complementary systems for flowing different kinds of molecules indispensable for making the energy transition a success including:

- A system for transporting methane (in which biomethane and synthetic methane will increasingly replace quantities of natural gas).
- A system for transporting hydrogen (H_2).
- A system for transporting carbon (CO_2).

Fluxys proposes a stepwise approach to achieving this:

- **Developing and connecting local clusters:** Fluxys aims to make hydrogen and other carbon dioxide (CO_2) infrastructure operational from 2026 through close collaboration with industry, market players and neighbouring operators. Fluxys envisions the development starting with local industrial clusters. Between these, hydrogen and carbon backbone infrastructure can develop allowing transfers between them so as to increase market size and improve security of supply. The hydrogen backbone also enables the wide deployment of hydrogen refuelling stations required to decarbonise mobility.
- **Mature backbone:** The hydrogen and carbon clusters and backbone development is also progressively complemented with multiple interconnections with neighbouring systems. For hydrogen this means that customers can rely on a growing European hydrogen market and have access to green hydrogen produced far away within the shortest possible period.

As other gas TSOs develop hydrogen backbones as well (cf. section 1.3), the hydrogen infrastructure in Belgium will continue to grow and reinforce the country's role as an essential energy hub for the NW Region.

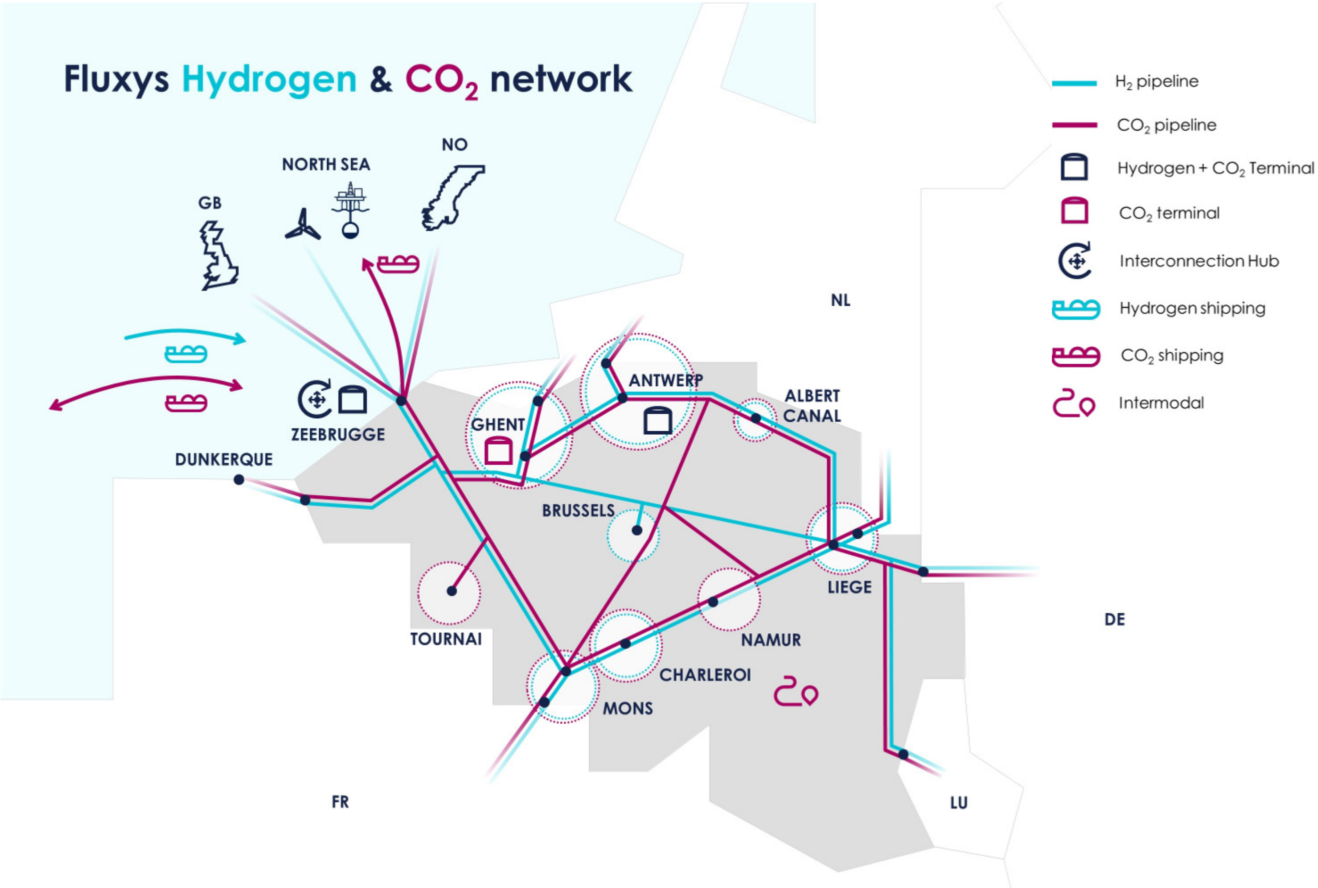


Figure 2: Long term infrastructure for H_2 and CO_2 (Source: Fluxys)

2.1.3 Hydrogen import coalition: Ready for the next step toward the Belgian hydrogen economy

In order to meet the challenge of the transition to a carbon-neutral society by 2050, we need to look beyond our own production of renewable energy generated domestically or offshore. The import of renewable energy plays an essential role in this respect. The study published by the hydrogen import coalition – a collaboration between seven major industrial players and public stakeholders – analyses the entire hydrogen import chain and concludes that this is both technically and economically feasible. This thorough feasibility study is the first tangible result of the collaboration between DEME, ENGIE, Exmar, Fluxys, Port of Antwerp, Port of Zeebrugge and WaterstofNet, each with its own specific and complementary expertise and experience. This study creates the initial base for concrete next steps, including pilot projects for the supply of sustainable energy by means of green molecules from countries where wind and solar are available in abundance to Belgian end users, among others.

After thorough analysis of all the elements, the study concludes that importing this form of renewable energy is a necessary and feasible solution to the growing shortage in Western Europe. Various types of hydrogen-derived carriers from a range of supply regions will be able to provide cost-competitive renewable energy and raw materials by 2030–2035. The most promising green energy carriers are ammonia, methanol and synthetic methane. These can be deployed through existing modes of transport such as pipelines and maritime transport in particular – and growing markets, encouraging a rapid start.

According to the study, this import of renewable energy through green hydrogen carriers will therefore become an essential part of the Belgian energy supply, complementing the sustainable transition based on domestically generated energy. Belgium has maritime ports and extensive pipeline infrastructure, is linked to the major industrial clusters and has the capacity to meet its own energy needs and those of surrounding countries.

As concrete next steps, the coalition will analyse how to prepare Belgian seaports to receive the hydrogen carriers of the future, seeking to maximise synergies to serve national interests. Specific pilot projects are being set up whereby the coalition can make maximum use of the Flemish expertise and strength in the area of logistics, industry and technology for the development of a sustainable economy and the climate transition both nationally and in the NW Region.

2.1.4 Hydrogen Delta Network

Gasunie and Fluxys are working to develop a national hydrogen network in the Netherlands and Belgium respectively. The two networks will link together in the port zone on the Dutch–Belgian border. The connection will supply hydrogen to the companies in the 60-kilometre port zone stretching from Vlissingen and Terneuzen in the Netherlands to Ghent in Belgium.

Working in close collaboration with industry, Fluxys and Gasunie are preparing for the construction of an open-access hydrogen network on both sides of the Belgian–Dutch border. All companies can connect to the infrastructure. The aim is to have the networks operational by 2026 and to join them at the border. This connection will mark the creation of one of the first cross-border open-access hydrogen networks in Europe. The two hydrogen networks will be connected in the towns of Sas van Gent in the Netherlands and Zelzate in Belgium, where natural gas is already flowing between the two countries. The pipes for the hydrogen network will mainly be laid along existing pipeline routes, minimising the impact on the environment.

Thanks to its scale effect, the cross-border connection will make a significant contribution towards developing the entire hydrogen value chain in the port zone, reorienting towards a green economy as well as supporting and expanding employment. The link will create an open market for green and low-carbon hydrogen in the entire port area, connecting suppliers and customers in a robust system. Linking the port zone into the national hydrogen infrastructure in the Netherlands and Belgium also gives companies access to a large hinterland as well as other industrial clusters and ports in Europe.

The cross-border industrial cluster in North Sea Port is the largest hydrogen hub in the Benelux. Every year, companies produce and consume 580,000 tonnes of hydrogen. This demand for hydrogen in the port zone will double by 2050 and will be fully sustainable by then. The cross-border network is to connect supply and demand on a large scale throughout the port zone and will boost the development of the hydrogen market. North Sea Port is well situated to develop into a hydrogen hub with a broad international appeal. This dovetails with the ambitions of and investments by Europe, the Netherlands, Belgium and Flanders in the energy and climate transition and the goal of becoming climate neutral by 2050.

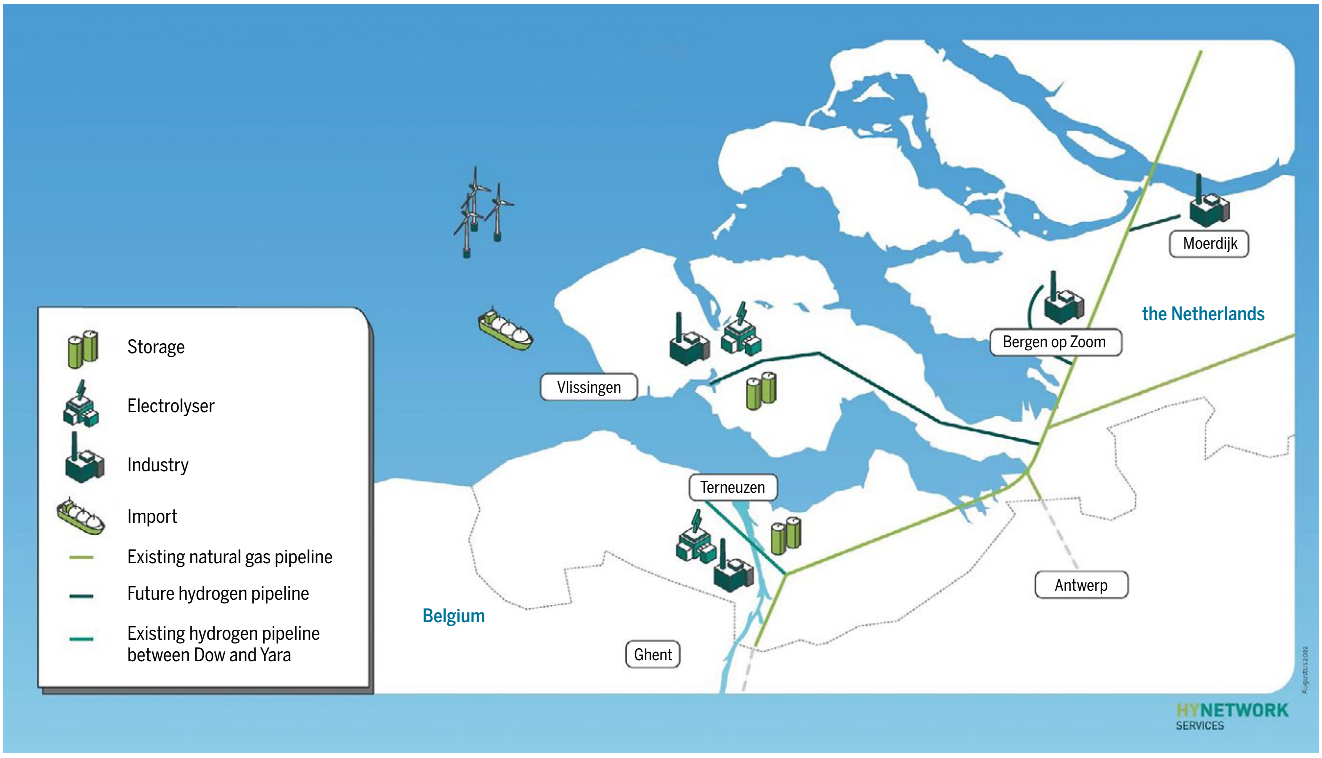


Figure 3: Hydrogen Delta Network (Source: Hynetwork NL)

2.1.5 Green ammonia import terminal

Fluxys, Advario Stolthaven Antwerp and Advario Gas Terminal have joined forces to study the feasibility of building an open-access green ammonia import terminal at the Port of Antwerp-Bruges. The project aims to offer the market a robust solution to its growing demands for importing and storing green energy and raw materials against a backdrop of ongoing decarbonisation.

By combining their strengths and expertise in logistics, terminalling and pipeline transmission, Fluxys, Advario Stolthaven Antwerp (a 50–50 joint venture with Stolthaven Terminals) and Advario Gas Terminal want to ascertain the optimum ammonia terminalling solution for North West Europe. They aim to have the terminal operational in 2027. Fluxys and the Advario terminals are now engaging with major industrial operators and energy suppliers to introduce their project.

Ideally located in the heart of Europe, at Belgium's Port of Antwerp-Bruges, the future terminal will deliver storage and multimodal send out solutions for ammonia (train, truck, barge and possibly ammonia pipelines connected to local industrial sites), while optionally also providing facilities to convert ammonia back into hydrogen. The terminal will also connect to the Fluxys open-access hydrogen network to ensure supply throughout North West Europe.

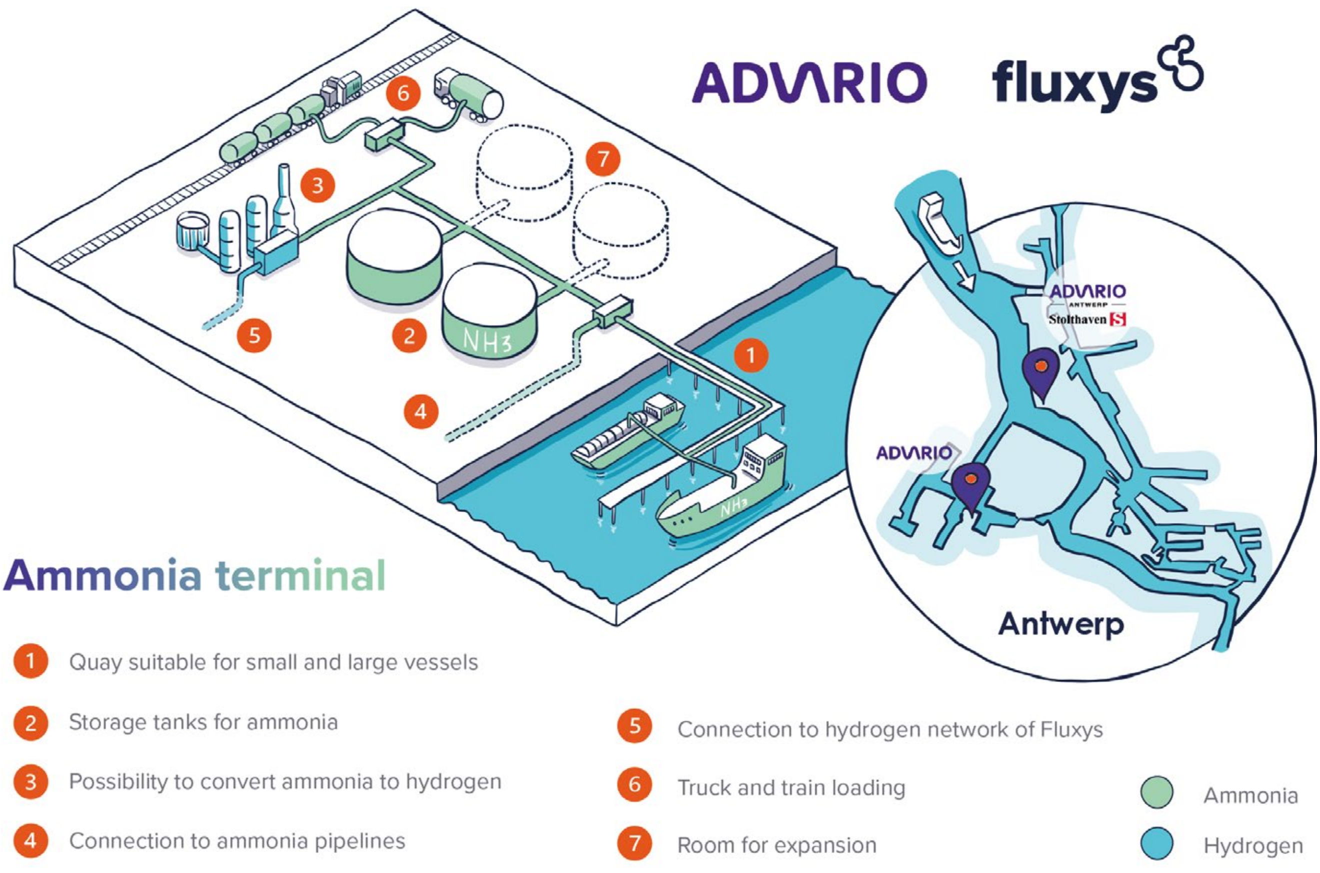


Figure 4: Illustration of the ammonia terminal (Source: Fluxys)

2.1.6 Ghent Carbon Hub

Besides the use of carbon-neutral energy, carbon capture, utilisation and storage (CCUS) is essential for CO_2 intensive industries to achieve net zero emissions, especially in hard-to-abate sectors with processes inherently generating CO_2 emissions.

Fluxys, ArcelorMittal Belgium, and North Sea Port are pressing ahead to develop a key infrastructure accommodating the CCUS chain. Ghent Carbon Hub is set up as an open-access hub to transport and liquefy CO_2 from emitters, provide buffer storage and load the liquefied CO_2 onto ships for onward permanent storage in Norway. The feasibility study has now started and commissioning is targeted for 2027. Ghent Carbon Hub will have a capacity to process 6 million tonnes of CO_2 per annum (MTPA), equivalent to around 15 % of Belgian industrial CO_2 emissions.

The project will benefit from Fluxys' wide experience in terminalling activities, while Fluxys is also developing an open-access CO_2 transmission backbone in Belgium. Ghent Carbon Hub connects into Fluxys' CO_2 backbone, allowing CO_2 emitters from the North Sea Port area and other industrial clusters to transport their captured CO_2 to the hub or locations of reuse.

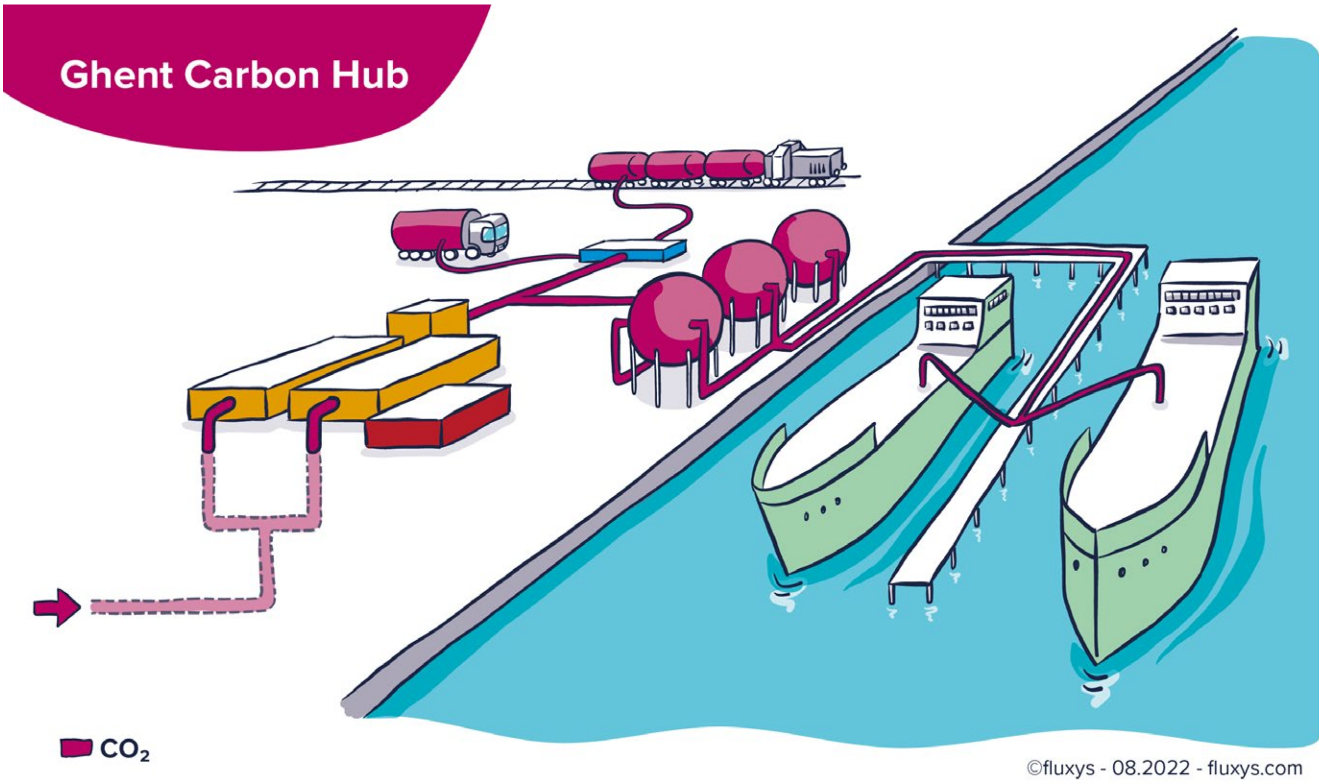


Figure 5: Illustration of the CO_2 terminal (Source: Fluxys)

2.1.7 The Antwerp@C project takes a major next step towards halving CO_2 footprint

Port of Antwerp is home to the largest integrated energy and chemicals cluster in Europe. This makes it the ideal location to set up new, cross-border collaboration projects for innovative CO_2 reduction. To this end, Air Liquide, BASF, Borealis, ExxonMobil, INEOS, TotalEnergies, Fluxys and the Port of Antwerp joined forces at the end of 2019 under the name of Antwerp@C, to investigate the technical and economic feasibility of building a CO_2 infrastructure to support future CCUS (Carbon Capture Utilization & Storage) applications. Carbon Capture & Storage (CCS) and eventually also Carbon Capture & Utilization (CCU) – i.e. reusing CO_2 as a raw material for the chemical industry – are seen as important routes in the Port of Antwerp's transition to a carbon-neutral port. This innovative cross-border CCUS project would be among the first and world's largest multimodal open access CO_2 export facilities.

Antwerp@C has the ambition to support industries' efforts towards a 50 % CO_2 emissions' reduction within the Port of Antwerp, Belgium, by 2030 through the creation of a common CO_2 infrastructure. With the ongoing engineering studies, the project has now reached a new milestone to achieve more sustainable, lower-carbon operations around the Port of Antwerp. The seven leading chemical and energy companies aim to make a significant contribution towards the climate objectives of Belgium and the EU. The project aims to collect and export CO_2 for sequestration in offshore capacities in the coming years and at reasonable costs or to make it available for potential future reuse.

After carrying out the feasibility study in 2021, Antwerp@C has now taken the decision to move on to the next phase and start engineering studies. These will further investigate the construction of a central "backbone" throughout the port of Antwerp along the industrial zones on both the Right and Left banks of the river Scheldt. Also part of the engineering studies is a shared CO_2 liquefaction unit with interim storage and marine loading facilities for cross-border shipping. These studies are partially funded by a Connecting Europe Facility (CEF) grant, which was awarded in October 2020, by subsidies from the Flemish government for the feasibility-phase and by contributions of all consortium participants. After the engineering studies have been finalised, a final investment decision for the first phase is anticipated in the first half of 2023.

In the meantime, Fluxys, Air Liquide and Pipelink (a subsidiary of Port of Antwerp) have successfully organised an 'Open Season' in order to map the initial demand for the CO_2 infrastructure which is proposed to be built. The Open Season was an invitation towards all companies in the wider port area of Antwerp to make their interest known for CO_2 transmission and/or CO_2 terminalling infrastructure in Antwerp. The response gathered from the market will be considered in order to take a final investment decision.

Picture courtesy of Fluxys/P. Henderyckx

2.1.8 CO_2 transport from Zeebrugge to the Norwegian Continental Shelf

Fluxys and Equinor have agreed to develop a major infrastructure project for transporting captured CO_2 from emitters to safe storage sites in the North Sea, connecting Belgium to Norway. The project is in the feasibility stage, with an investment decision expected by 2025.

Carbon capture, transport and storage (CCS) is essential for achieving significant CO_2 emission reductions. This project by Equinor and Fluxys offers the NW Region a robust and flexible solution for large-scale decarbonisation.

The project includes a 1,000 km CO_2 export trunkline operated by Equinor which will transport CO_2 for safe and permanent storage under the seabed on the Norwegian continental shelf. The offshore trunkline will connect in Zeebrugge to an onshore CO_2 transmission infrastructure built and operated by Fluxys. The open-access CO_2 transmission system will give emitters in Belgium and surrounding countries the opportunity to connect to safe and reliable CO_2 stores in Norway. As it goes, liquefied CO_2 shipped from neighbouring hubs could be connected to the Zeebrugge facility, further increasing the geographical reach of the project. A pipeline branch to the port of Dunkirk is also envisaged and additional connections to other North-West European countries will be assessed as well.

The joint initiative by Equinor and Fluxys aims to develop the CO_2 infrastructure project ready for commissioning before the end of this decade. The offshore pipeline is planned to have a transport capacity of 20 to 40 million tonnes of CO_2 per annum, meeting an emerging need for CCS from multiple European industrial players.

The large-scale pipeline transmission solution offers businesses an easy-to-use logistics chain from capture to storage. It is both efficient and economical for large volumes of CO_2 and allows for ample operational flexibility. Fluxys and Equinor will be engaging with interested parties such as major emitting industries to present the project.

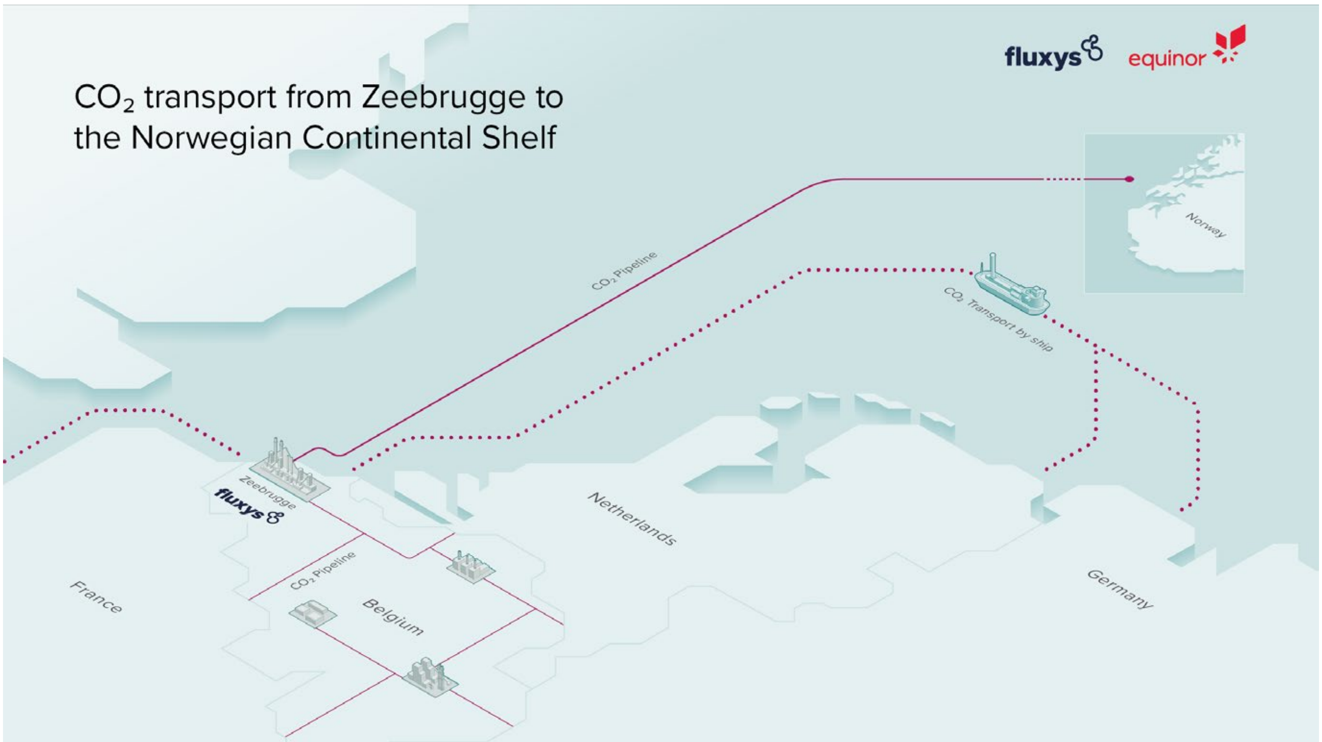


Figure 6: CO_2 infrastructure from Belgium to Norway (Source: Fluxys)

Figure 7: Zeebrugge LNG terminal (Source: Fluxys/Wim Robberechts)

2.1.9 BioLNG at the Zeebrugge LNG Terminal

In 2021 Fluxys LNG developed a scheme to allow bio-LNG at its Zeebrugge LNG terminal. Biomethane injected in the European gas grid can be transported (via mass balance) to the Zeebrugge Terminal where it can enter the terminal via reverse nomination. The incoming quantity of gas is then liquified using the rest-cold present in the Terminal. The biomethane certificate (proof of sustainability) is converted in a bio-LNG certificate which is certified by a European recognised voluntary scheme: ISCC EU (international sustainability certification & carbon certification).

It allows the bio-LNG to be stored and reloaded as bio-LNG to a small-scale ship or truck and to be further traded on the EU biofuel market. The project was initially set-up as a pilot with the support of the Belgian regulator CREG and was integrated in the terminal contracts as a full regulatory service accessible to all terminal users. The plant has a capacity to produce on average 1 TWh of bio-LNG per year and bio-LNG has already been delivered to Germany, Sweden, Norway and Belgium, and as demand for bio-LNG is rising fast, it is expected to become a common EU commodity in the near future, mainly for heavy duty transport and as a renewable maritime fuel.

2.2 CZECH REPUBLIC

2.2.1 Central European Hydrogen Corridor

The Central European Hydrogen Corridor (CEHC) initiative explores the feasibility of creating a hydrogen "highway" in Central Europe for transporting hydrogen from major hydrogen supply areas in Ukraine via Slovakia and the Czech Republic to hydrogen demand areas in Germany. The hydrogen corridor will also enable the transport of hydrogen between hydrogen production facilities and hydrogen consumers in the Czech Republic and Slovakia.

The Central European Hydrogen Corridor initiative is being promoted by a group of four leading Central European gas transmission infrastructure companies in Ukraine, Slovakia, the Czech Republic, and Germany, working together to create a Central European hydrogen transport infrastructure. The participating companies are:

- Gas TSO of Ukraine
- EUSTREAM (the Slovak gas TSO)
- NET4GAS (the Czech gas TSO)
- OGE (a leading German gas TSO)

Ukraine is a very promising future major supply area of hydrogen that offers excellent conditions for large-scale, green hydrogen production. Ukraine is also well connected to Europe by its large natural gas pipeline system that can be repurposed to transport hydrogen to Central Europe.

Slovakia and the Czech Republic are operating a large natural gas pipeline corridor connecting Ukraine with European demand areas. The Slovak, Czech and German gas pipeline systems can be repurposed to transport hydrogen.

Furthermore, Germany is expected to be one of the largest demand areas of hydrogen in Europe. Importing significant amounts of hydrogen is essential to meet projected demand in this region.

The CEHC initiative believes that such a corridor for the transportation of hydrogen from Ukraine to Germany can be created based on repurposed existing gas infrastructure, combined with targeted investments in new dedicated hydrogen pipelines and compressor stations. This enables dedicated hydrogen transport over long distances at affordable costs.

The CEHC initiative have already started to explore the technical feasibility of creating a Central European Hydrogen Corridor for the initial transportation of up to 120 GWh per day of pure hydrogen from Ukraine to Germany by 2030.

As a general note, repurposed infrastructure in the Czech Republic will be ready to transport hydrogen also for different regions than anticipated in this initiative.

Figure 8: The Central European Hydrogen Corridor initiative
(Source: CEHC)

2.2.2 Greening of Gas

NET4GAS, s.r.o. (CZ TSO) is a project promoter of *the Greening of Gas project (GoG)* which aims to build and connect to the Czech gas transmission system a facility to demonstrate the operational and industrial feasibility of energy transition projects and prove the future role of gas infrastructure.

The GoG is prepared as a pilot project which aims to produce renewable gases using the unique Power-to-Gas technology. The project consists of a combination of two technologies. One is the production of hydrogen by water electrolysis from renewable electricity and the second one is a biogas purification technology (bio methanation) with a subsequevent production of synthetic methane. The project also aims to test injection of methane and possibly hydrogen into the transmission and/or distribution gas systems in the Czech Republic.

The current project schedule expects its commissioning around 2025. The operator of the facility has not been decided yet due to legislative requirements, including the requirements for unbundling of the transmission system operator. It is the first project of such type which is prepared in the Czech Republic. Therefore, it is associated with all difficulties that accompany anything innovative, not tested in current environment and without legal framework.

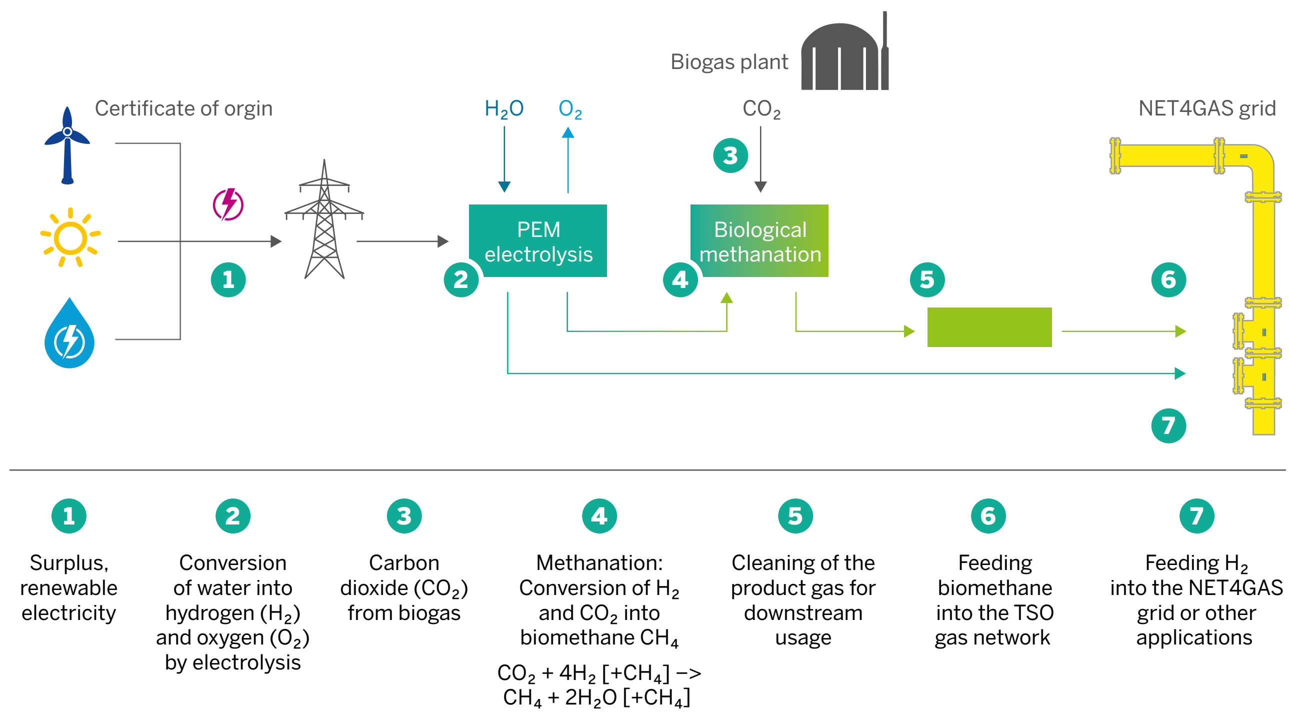


Figure 9: Schematic description of the prepared Power-to-Gas facility (Source: NET4GAS)

2.3 DENMARK

2.3.1 Increased biomethane reverse flow capacity

In Denmark, the vast majority of biomethane production facilities are connected to the gas distribution grid. A prevailing challenge for Energinet and the Danish gas DSO, Evida, is maintaining system balance as supply of biomethane in local distribution grids exceed the gas demand. This has typically been an issue in the summer with low gas demand and high biomethane supply, but the need for system balance of biomethane is expected to reach well into spring and autumn in the coming years.

To maintain system balance Energinet owns and operates four reverse flow facilities, which compresses biomethane from 20/40 bar to 80 bar and removes odor. The need for system balance of biomethane in the distribution grid is escalated with high gas prices lowering gas demand and new national energy policies stimulating the growth of biomethane and phase out of primarily gas demand for heating.

To accommodate the recent development, Energinet is currently working to increase the reverse flow capacity, by establishing seven new and expanding two existing reverse flow facilities between 2023 to 2026. The objective of this project is to ensure the integration of excess biomethane in the distribution grid into the transmission grid by reverse flow across the country. Over a 30-year timespan the new facilities are expected to handle between 10–19 bcm biomethane. Based on current predictions and assumptions this project ensures sufficient infrastructure and reverse flow capacity to integrate biomethane in the Danish gas system well beyond 2030 and for Denmark to achieve a share of biomethane over 100 % compared to the gas consumption.

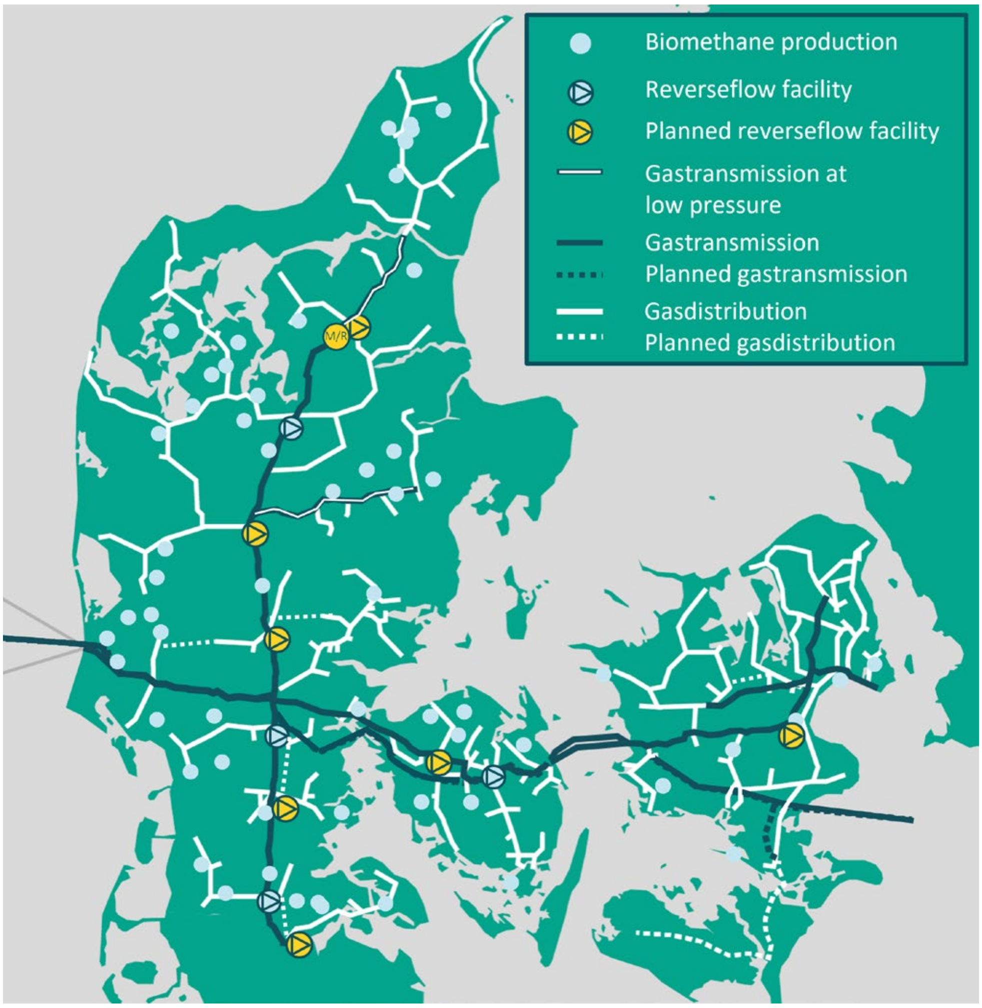


Figure 10: Existing and planned reverse flow and biomethane production facilities in Denmark (Source: Energinet)

2.3.2 Danish hydrogen pipeline

By 2030 the Danish government aims to have 4–6 GW electrolysis capacity installed. Based on publicly known hydrogen projects within the industry more than 7 GW of electrolysis capacity is planned to be installed by 2030.

Energinet and The Danish Energy Agency have carried out a market dialogue regarding the need for hydrogen infrastructure. Based on the input this project is a study on converting parts of the existing methane infrastructure and build out of new hydrogen pipelines connecting possible Danish hydrogen production with e.g., hydrogen offtake, hydrogen storage and/or cross-border interconnections.

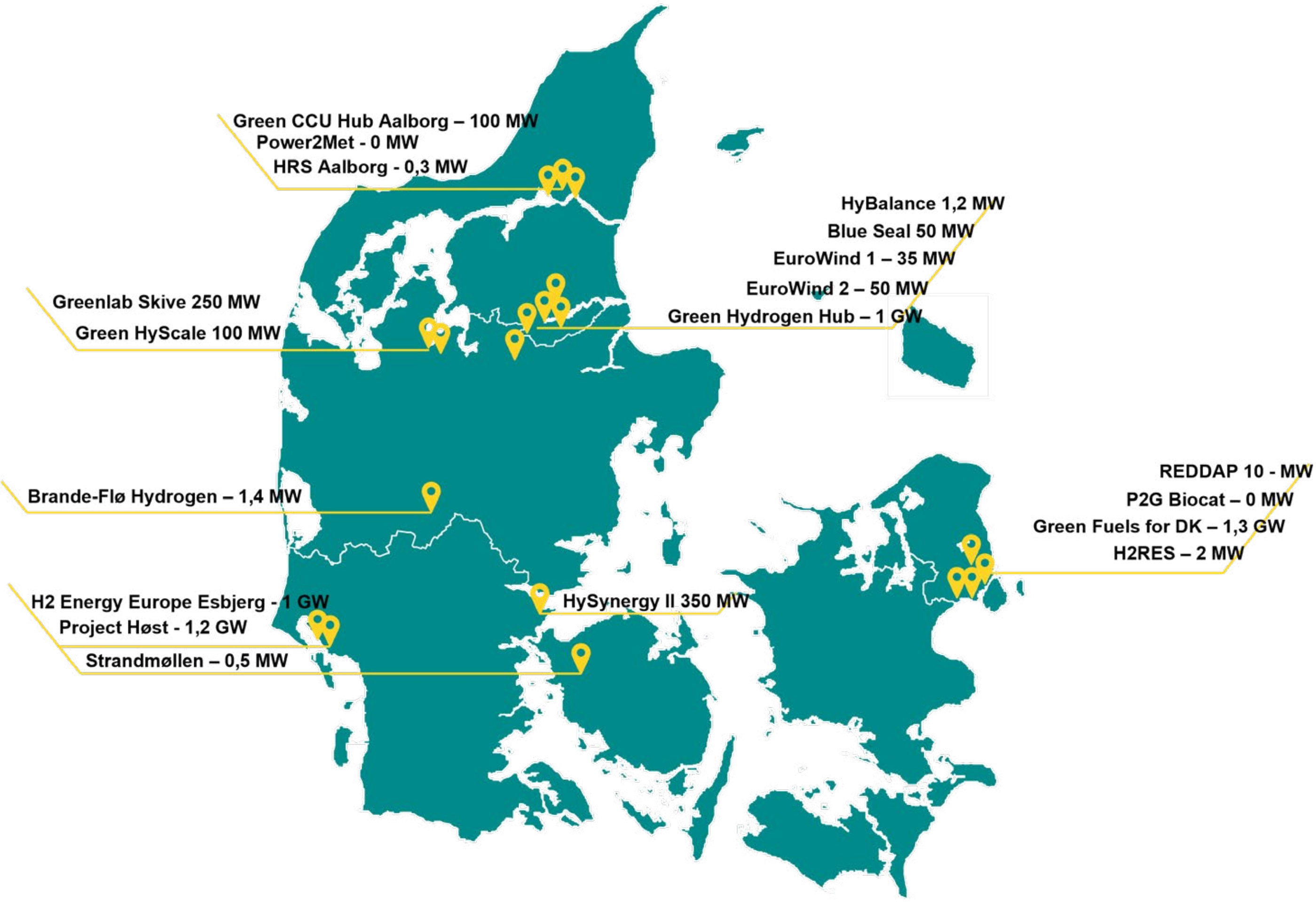


Figure 11: Publicly known hydrogen projects in Denmark (Source: Hydrogen Denmark)

Energinet and Evida, have officially been given the possibility to own and operate infrastructure for hydrogen which also includes possible conversion of existing methane infrastructure. Before an potential conversion will take place, Energinet has in May 2022 initiated a feasibility study for the 2030 stage of the Danish Hydrogen Backbone, which enables hydrogen exports from Jutland to Germany including access to underground hydrogen storage and that is aligned with the European Hydrogen Backbone. Energinet and Gasunie published in April 2021 a pre-feasibility study highlighting the export potential and technical feasibility of a cross-border hydrogen infrastructure between Denmark and Germany.

2.3.3 Danish Hydrogen Storage

This project is a study of an underground hydrogen storage system based on existing infrastructure enabling flexibility and storage of hydrogen for Danish hydrogen production and consumption. The project scope is conversion of an existing underground cavern from natural gas to hydrogen storage with a capacity of 200 GWh in 2025 and 400 GWh in 2030. The market dialogue regarding the potential need for hydrogen infrastructure carried out by Energinet and The Danish Energy Agency, identify requirements for flexibility and storage of hydrogen. The Danish strategy on PtX mentions the importance of hydrogen storage as part of the infrastructure but further national regulation on hydrogen awaits.

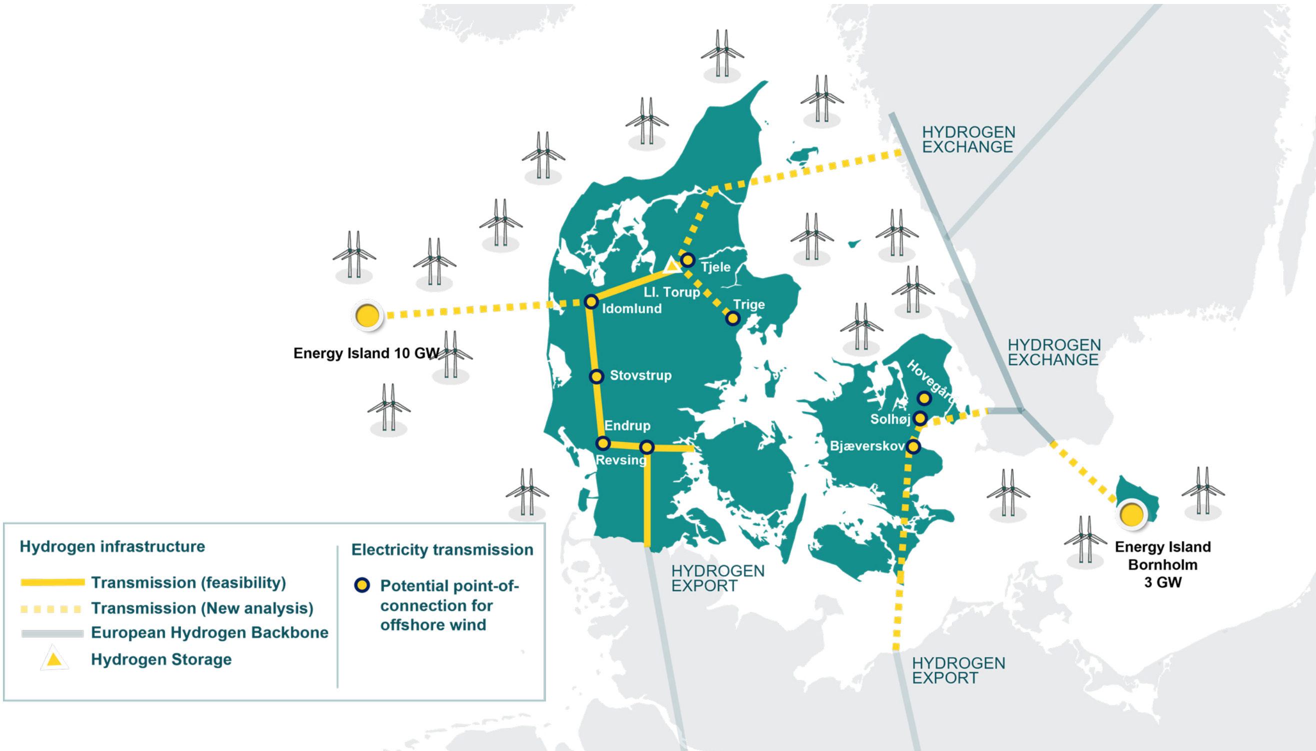


Figure 12: Example of possible hydrogen infrastructure in Denmark (Source: Energinet)

2.3.4 Pilot for storage of CO_2

Gas Storage Denmark, a subsidiary of Energinet, has started preparatory activities for a CCS pilot project with the goal of permanently storing 2.5 million tonnes of CO_2 underground by 2030. The project is expected to be able to store CO_2 from late 2024 with a yearly capacity of 500,000 tonnes from 2025. The preparatory activities will help advance CCS-value chains and large-scale storage of CO_2 in Denmark. With this scope, the pilot will play an important part in underpinning the Danish climate ambitions.

The pilot will utilise existing infrastructure at Gas Storage Denmark's facility in Stenlille and will not have any implications for the existing natural gas storage operations.

In Denmark there has been allocated public CCUS-funds. The Danish Energy Agency manages a fund of 16 billion DKK for projects developing the entire CO_2-value chain from capture to transport and storage of CO_2. Therefore, there are multiple ongoing CCS- and CCU-projects in Denmark besides Gas Storage Denmark's pilot.

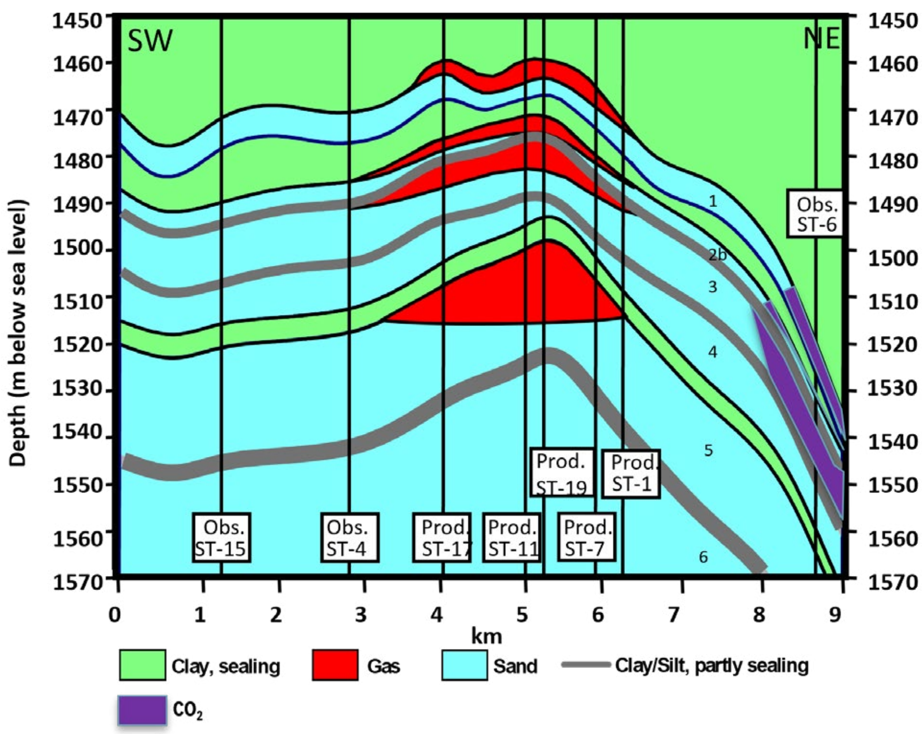


Figure 13: Schematic of underground CO_2 storage in Denmark (Source: Gas Storage Denmark)

2.4 FRANCE

2.4.1 Biomethane development in France

In France, hundreds of biomethane upcoming plant projects are registered to inject in the distribution and transmission gas system. However, in many cases, the injection capacity of the local distribution system is not enough to integrate such production. Furthermore, decentralised production has significant impacts on the gas infrastructure operation (monitoring, maintenance, coordination with the stakeholders etc.).

The impact on the gas network consists in backhaul installations and mutualised compressors, and meshing distribution grid. The regular framework established in 2019 ensures producers the right to inject its biomethane into the grid, considering reasonable mutualised investments for the network.

Network investments are identified for each local area through zoning plans, according to the configuration of the networks, the projects recorded in the area, and the methanisable potential for the area. The completion of all the investments identified in these local network development plans would result in a total of € 950 million split between network reinforcements and network extensions (distribution network meshing and for connections of producers).

2.4.2 Low-carbon gas and hydrogen

GRTgaz and Teréga strongly supports the integration of low-carbon gas, produced by pyrogasification or thermal gasification, in their network as well as the development of dedicated hydrogen networks.

Therefore, GRTgaz has set up a Research & Development programme for integrating low carbon gases into its network or retrofitting existing gas networks into dedicated hydrogen networks. This programme is led by its Energy Research and Innovation Centre (RICE). It plans to define the safety issues facing facilities (integrity of pipes, network equipment and accessories and associated maintenance procedures) and the management of the network (adaptation of injection technologies, gas analysis equipment, compression equipment, metering equipment, invoicing systems and control tools) under optimal safety conditions and in the most cost-efficient way. It includes the following initiatives:

- FenHYx, a research platform for hydrogen: FenHYx is a research, innovation and European cooperation platform on new gases including hydrogen. Its purpose is to define the technical, economic and regulatory conditions for injecting hydrogen and low-carbon gases into the gas infrastructure. Developed with the support of the Ile-de-France Region, the FenHYx platform in particular aims to reproduce the features of gas networks and especially those of the gas transmission networks: compression, expansion, measurement, analysis, injection loop, etc. Trials, at different pressures and concentrations of hydrogen and methane, will be used to test, assess and certify innovative processes and equipment for producing new gases including hydrogen. Through this platform, GRTgaz wishes to encourage the collaboration with other operators – such as European gas network operators but also equipment suppliers.

- Jupiter 1000, first industrial demonstrator of Power-to-gas in France, located in Fos-sur-Mer: "Jupiter 1000" is the first industrial demonstrator of Power to Gas with a power rating of 1 MWe for electrolysis and a methanation process with carbon capture. The installation is based on an innovative methanation technology and CO_2 is captured on a nearby industrial site. The first hydrogen molecules have been successfully injected into the transmission system in February 2020 and synthetic methane in July 2022. This project involve several industrials and public partners: GRTgaz, Teréga, RTE, CEA, Asco Industries, McPhy Energy, Atmostat, Leroux and Lotz Technologies, CMA CGM and is supported by the European Union, the French Energy transition Agency (ADEME) and the Region Sud.

At Teréga, R&I involves around 60 employees spread over all departments, from monitoring and foresight to the implementation of innovations. This internal organization – coordinated and managed within the Strategy, Innovation and Development Unit, attached to General Management – is one of Teréga's strengths. It firmly roots innovation at the heart of the company's approach through the IMPACTS 2025 Innovation Plan, an R&I roadmap for 2025 developed in conjunction with Teréga employees which defines eleven programmes for regulated transmission and storage activities. Each programme encompasses a set of projects based around a strategic development or business optimisation theme, linked directly to the company's operational needs.

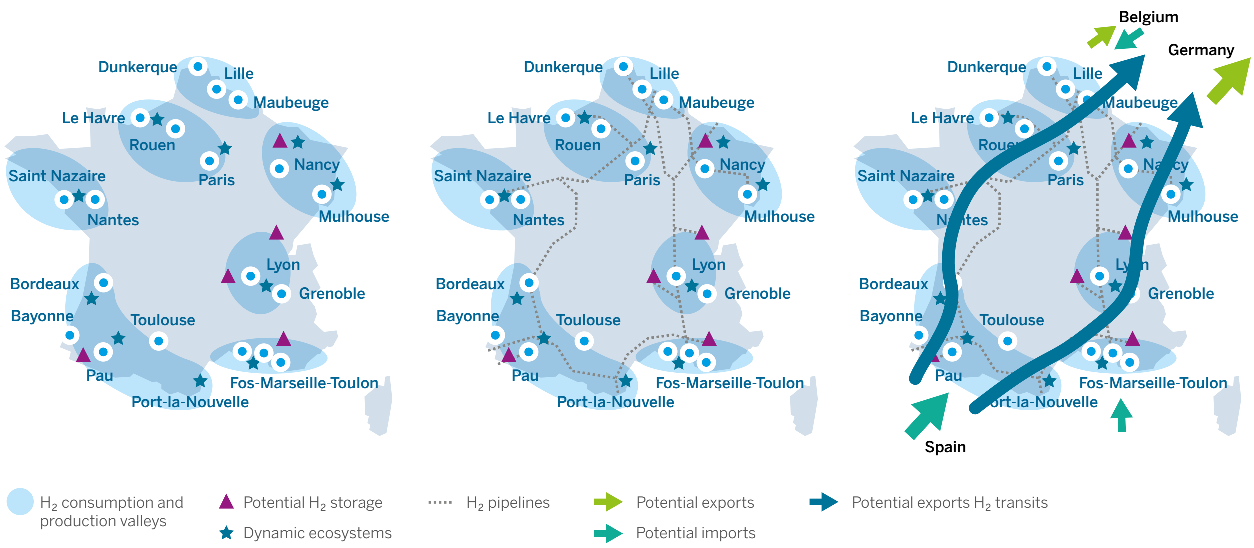


Figure 14: Deployment of hydrogen as an energy carrier

Teréga is involved in the IMPULSE 2025 project which aims at implementing a "smart multi-energies system" to interconnect different energy networks (gas, power, heat) to create synergies and improve energy efficiency. It includes studies and the building of a pilot demonstrator.

The deployment of a national hydrogen transport grid is crucial to supporting the development of the sector. In June 2021, Teréga and GRTgaz launched the first national consultation of the low-carbon and renewable hydrogen market to identify the needs of actors in the hydrogen market, taking existing gas transport and storage infrastructures into account. A consolidated joint vision of the future low-carbon and renewable hydrogen market was published in March 2022.

Seven Hydrogen valleys are emerging in major industrial areas where most of the hydrogen production is located. The hydrogen market will develop:

- in the short term from local ecosystems favourable to its production and consumption, particularly for industrial and transport uses;
- In the medium term, the creation of hydrogen valleys interlinking local ecosystems via a regional pipeline-based transport grid, integrating hydrogen storage infrastructures from the very outset, to facilitate balancing and security of supply;
- In the long term, the structuring of an interconnected grid at European level for pipeline-based transport, incorporating storage infrastructures and ensuring transit into neighbouring countries.

Some initial works for converting natural gas network arteries into dedicated hydrogen pipes to support the emergence of the first hydrogen valleys have started. Territorial workshops have been organised in order to study existing or future CO_2-H_2 complementarities at ecosystem level and to consolidate stakeholders' needs and expectations in terms of hydrogen and CO_2 transport infrastructures. Those first territorial workshops confirmed the maturity of hydrogen needs in several territories:

MosaHYc (Moselle Sarre HYdrogene Conversion) project

The Moselle-Sarre-Luxembourg ecosystem which, at the crossroads of European transport and energy infrastructures, is home to the MosaHYc project to develop a cross-border hydrogen transport grid, largely as the result of converting natural gas transport pipelines.

The MosaHYc (Moselle Sarre HYdrogene Conversion) project, in partnership with the German network operator Creos Deutschland, aims to convert 70 km of gas pipes between France, Germany and near to the Luxembourg border. It will connect sites producing hydrogen by electrolysis with current and future consumption areas, for use in mobility (buses, refuse trucks, heavy good vehicles, trains) and industry. For GRTgaz, the project would also be the first demonstrator in France to convert existing natural gas pipelines for the transmission of pure hydrogen. It has received the support of the French Energy Transition Agency ADEME.

The RHYn project (Rhine HYdrogen Network)

The Bâle–Mulhouse–Colmar–Fribourg-en-Brisgau ecosystem with the Chalampé area, currently the second-ranked hydrogen consumption area in France, with potential interaction with Germany and Switzerland.

The RHYn project (Rhine HYdrogen Network) aims to develop the Upper Rhine's hydrogen ecosystem by connecting the Dessenheim area with the Chalampé-Ottmarsheim industrial area by 2028 – together with the Mulhouse urban area (see map opposite) so as to meet its own mobility requirements. In subsequent phases, the network may be extended to the south towards Basel in order to supply the airport area, and to the north towards Marckolsheim to supply its industrial sites. GRTgaz is planning to reuse as much of the existing natural gas infrastructure as possible: of a total of 100 km of hydrogen network, at least 60 km will be converted pipeline. The pipeline will have the capacity to transport 125,000 tonnes of hydrogen per year (equivalent to 900 MW of production by electrolysis), and could reduce carbon emissions by up to 1 million tonnes of CO_2 annually. As part of this vision, GRTgaz will investigate possible interconnections with the regions of Baden-Württemberg in Germany and Basel in Switzerland.

The industrial port zone (IPZ) of Dunkirk

The industrial port zone (IPZ) of Dunkirk, home to industries emitting large quantities of CO_2 (20 % of CO_2 emissions from the industrial sector in France), particularly in the iron and steel sector, which envisages CO_2 capture, storage and utilisation, alongside the use of hydrogen, in its decarbonisation strategies. Several projects are in developments in this dynamic industrial hub.

A cross-border project between France and Belgium in the Hainaut Region

GRTgaz in France and Fluxys in Belgium work together towards a cross-border 100 % hydrogen transportation network in the Hainaut Region. The ambition of the project is to provide a 70 km regional-size hydrogen infrastructure located near the cities of Valenciennes in France and Mons, La Louvière and Feluy in Belgium to connect various hydrogen producers and consumers. Thus, the project could contribute to decarbonising industry uses as well as future mobility uses and address major environmental and economic challenges in this historical industrial region. This regional project is a first step towards a wider cross-border interconnected hydrogen network between Belgium and France. The project's commissionning is forecasted in 2027.

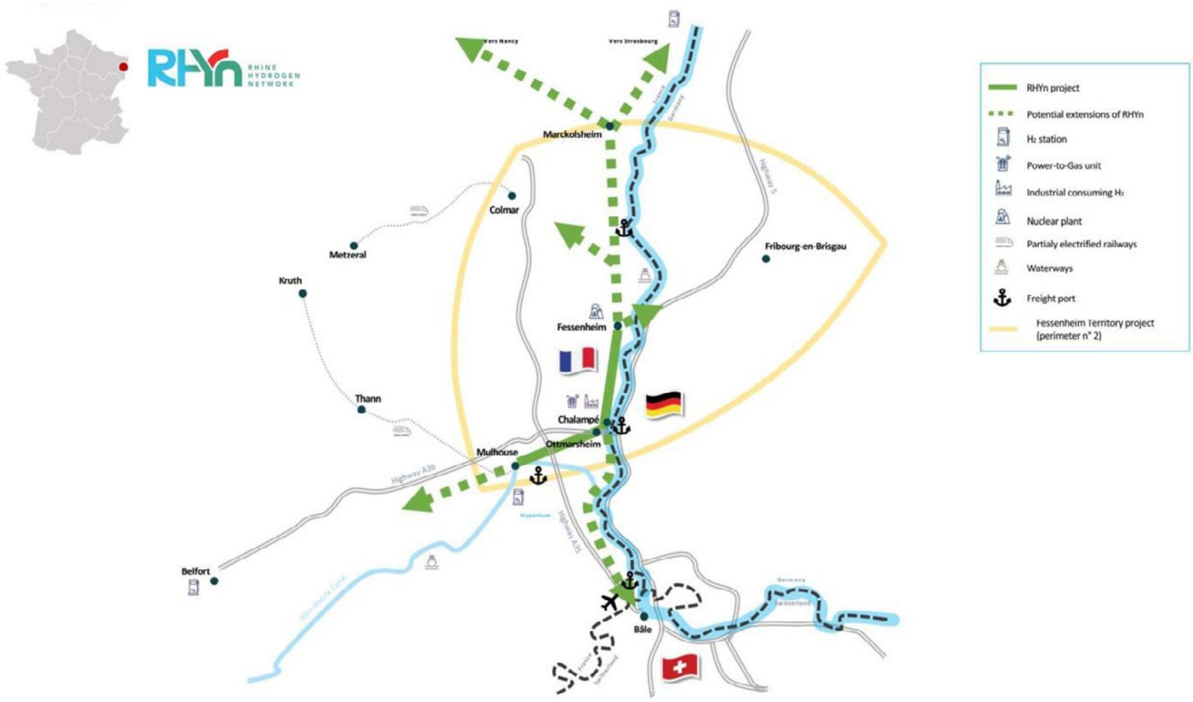


Figure 15: The RHYn project (Rhine Hydrogen Network)

The Fos-Marseille hydrogen valley

The Fos-Marseille hydrogen valley: To address decarbonisation needs of industries in the area, The HYnframed project aims to develop a hydrogen transmission pipeline from Manosque to the industrial port of Fos-sur-Mer, in the vicinity of Marseille in the South of France. The 150-km infrastructure will be composed mainly of new built pipelines. However, the project will investigate the opportunity to repurpose existing pipelines especially in the industrial area of Fos-sur-Mer. The project will foster the decarbonisation of a major CO_2-emission hub in France by connecting industrial consumers (refinery, steel-making and petrocheminal sectors) located in Fos-sur-Mer to a low-carbon hydrogen production, backed by a H_2-storage facility in salt caverns in Manosque, and developed by the Hygreen Provence consortium. The project benefits from the support of the French Energy Transition Agency ADEME and the Region Sud.

The Lacq-Pau-Tarbes cluster

In the Lacq-Pau-Tarbes cluster, Teréga is developping three projects:

- **The Hygeo project's** purpose is to develop a geological renewable energy storage installation in the form of the green hydrogen (H_2). It includes the installation of electrolysis units to transform renewable electricity into hydrogen ($P2H_2$). The project will offer flexibility to the electricity grid, providing a source of supply of electricity (P2P), as well as the possibility of providing H_2 for direct consumption or for injection in the gas network.
- **The Lacq Hydrogen project** consists of developing an H_2 interconnection between France and Spain with the aim of supplying the Lacq industrial area. The hydrogen is expected to be produced in Spain, sourced from the electrolysis of wind and solar power. It will then be transported via a hydrogen-converted pipeline to be consumed by the industrialists or stored in the Teréga infrastructures in this area.
- **The Pycasso project,** led by Teréga and industrial partners, aims to create a CCUS hub based on a shared vision as well as a coherent and optimised territorial approach for Occitanie, Nouvelle Aquitaine and the Spanish Basque Country regions. It relies on the decarbonisation plans of local communities to consider emissions reduction. Large-scale storage of CO_2 is envisaged in the Lacq area, in depleted gas fields.

The HY-FEN project (GRTgaz) and the East Interconnector Spain/France (Teréga/Enagas) will link these projects and create an interconnected French hydrogen transmission network via pipeline connected to Spain and Germany and national storages.

Composed as much as possible of existing assets converted to hydrogen, Hy-FEN represents 1200 km of pipelines across France. As part of a European South-North corridor, HY-FEN will link French hydrogen valleys as well as significant hydrogen potential from highly competitive renewable electricity (solar and wind power) in Southern Europe to future industrial consumption areas in North-Western Europe.

The East Interconnector Spain/France project led by Teréga and Enagas will connect the Iberian Peninsula to GRTGaz via a dedicated new pipeline located east of the Pyrenees in 2030.

Subsequently, other hydrogen interconnections could be created between France and Spain, in particular via the conversion of natural gas pipelines, through projects Hygeo and Lacq Hydrogen (see below for description of these), for a length of approximately 260 km. Finally, a new pure hydrogen pipeline is being studied in the Basque Country to be able to transit the important Spanish hydrogen production by 2040.

These infrastructures would contribute to the emergence of one of the major hydrogen import corridors via the Mediterranean identified in the REPowerEU Plan and aligned with the Southwest corridor in the EHB publication.

Figure 16: HY-FEN project and the East Interconnector Spain/France

2.5 GERMANY

The German hydrogen network plans take account of the hydrogen transmission capacities needed for a climate-neutral Germany. The planning is based on a scenario framework in which climate neutrality is reached in 2050. However, the hydrogen pipelines required for a climate-neutral energy system could be built as early as 2045 by adjusting the relevant planning periods accordingly.

In the scenario, future hydrogen demand is primarily met by imports. The capacities at the cross-border IPs are based on the assumed hydrogen production potential in the different regions.

The total length of the H_2 network in 2030 is about 5,100 km, some 3,700 km of which are repurposed natural gas pipelines. The underlying scenario for the H_2 network 2030 assumes that there is a 71 TWh demand for hydrogen (net calorific value) as an energy source and feedstock. (Gray) hydrogen quantities that will probably still be used in 2030 as part of various process chains involving methane are not included in this figure. In the simulation, the H_2 network 2030 meets a peak demand of around 10 GWh/h of hydrogen. Given the power-to-gas expansion targets defined in the National Hydrogen Strategy, the TSOs included 5 GW_{el} of electrolyser capacity for 2030, most of which is located in northern Germany. The German government has announced to increase the target electrolysis capacity to 10 GW_{el} till 2030. Quantities required by the transport and heating sectors will presumably not be shipped via the hydrogen network in 2030 but will predominantly be generated locally. Capital spending until 2030 is expected to amount to about 6 billion euros. This estimate includes investments for transmission pipelines including compressors, which are required for Germany-wide hydrogen transportation[22].

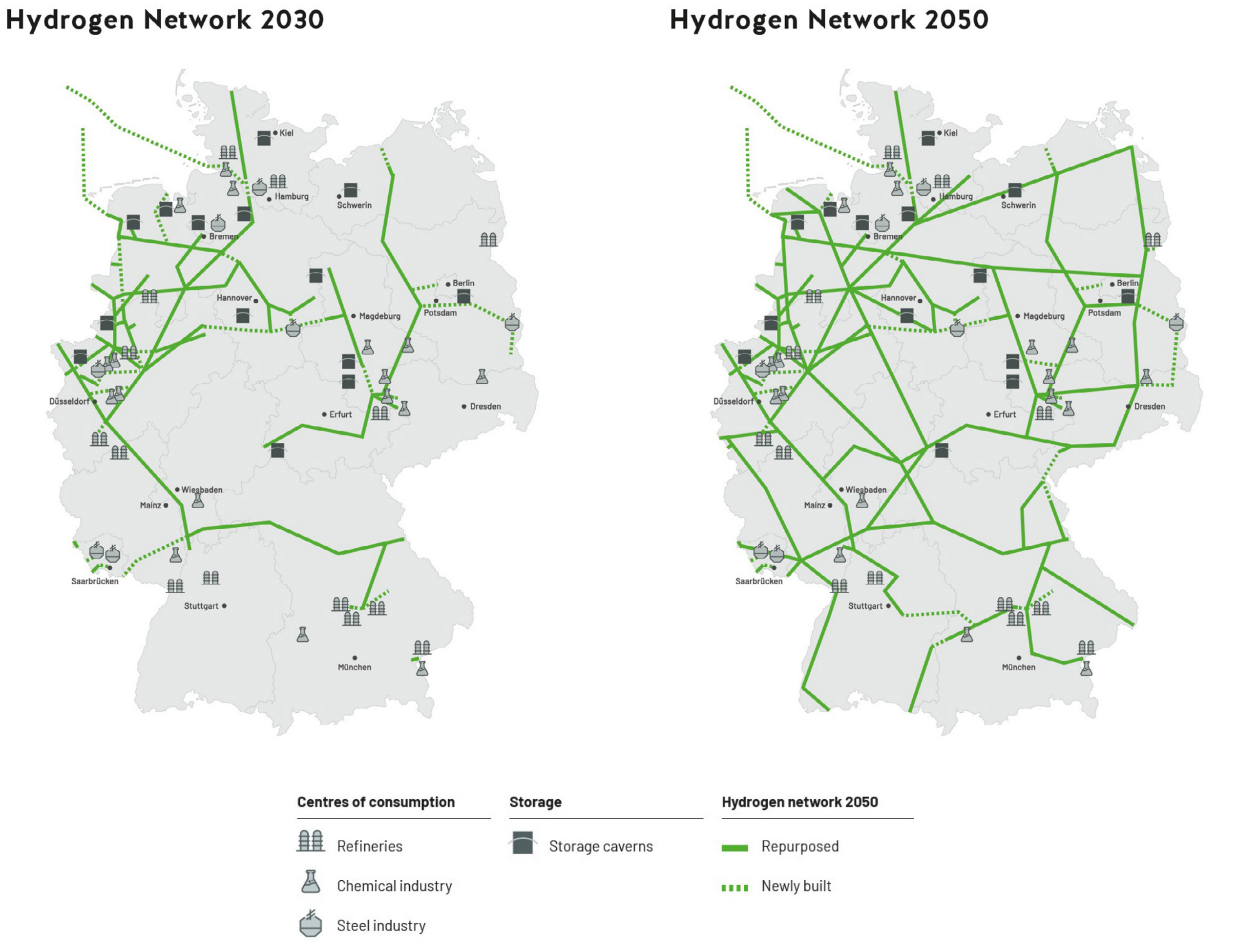


Figure 17: Hydrogen Network 2030 and 2050 of FNB Gas (Source: 2030, 2050)

22 https://fnb-gas.de/en/hydrogen-network/hydrogen-network-2030-towards-a-climate-neutral-germany/

The total length of the H_2 network 2050 is about 13,300 km, some 11,000 km of which are repurposed natural gas pipelines. The underlying scenario assumes that the demand for "green" methane will be similar to the demand for hydrogen. The assumption is, that green methane will be available in a carbon neutral set-up. In a scenario where less methane is used (as described, for example, in the recently published dena pilot study Towards Climate Neutrality[23]), further optimization potential could be leveraged by converting more pipelines to pure hydrogen. The planned hydrogen transmission network is designed for an energy quantity of 504 TWh (net calorific value) at a peak demand of around 110 GWh/h. The scenario used by the TSO is based on the dena pilot study I TM95 scenario[24]. From this study approx. 63 GW of electrolyser capacity for 2050 is used, most of which is located in northern Germany. The cost estimate for the hydrogen infrastructure shows that an efficient hydrogen transmission system can be built at comparatively low cost. According to this estimate, total investments until 2050 would amount to some 18 billion euros. The estimate includes investment spending for hydrogen transmission at supra-regional level. It does not include, for example, the costs associated with the conversion of storage infrastructure, offshore pipelines or pipelines to connect individual generation plants and individual consumers to the grid[25].

23 https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2021/Abschlussbericht_dena-Leitstudie_Aufbruch_Klimaneutralitaet.pdf

24 https://www.dena.de/fileadmin/dena/Dokumente/Pdf/9261_dena-Leitstudie_Integrierte_Energiewende_lang.pdf

25 https://fnb-gas.de/en/hydrogen-network/hydrogen-network-2050-for-a-climate-neutral-germany/

2.5.1 H_2ercules – The hydrogen fast track

The development of a hydrogen infrastructure is a crucial building block for the decarbonisation of Germany and the diversification of its energy supply. To accelerate this important process, OGE and RWE have developed the national infrastructure project “H_2ercules”, which will supply consumers in the south and west of Germany with green hydrogen from domestic production and via import routes.

Therefore, up to 1 GW of new electrolysis capacity and 1,500 km of pipeline are planned by OGE and RWE. For the most part, pipeline conversions of the existing natural gas network are planned, supplemented by new constructions. The conversion of natural gas pipelines is not only the more cost-efficient solution, but also allows for a faster timeline. It is currently planned to implement the project in two steps by 2028 and 2030 in order to connect industries to the hydrogen supply as early as possible. This cross-value-added co-operation should overcome the chicken-and-egg problem in XXL format and pave the way for other projects as well.

While it will be OGE’s task to convert the required natural gas pipelines to hydrogen and build new pipelines, RWE will build up the electrolysis capacity and import additional green hydrogen. In addition, gas-fired power plants with at least 2 GW will be converted to hydrogen and gas storage facilities at the Dutch border will be connected to the hydrogen supply system to create further backup capacity.

H_2ercules opens up new opportunities to connect Germany to essential import routes – initially via pipelines from Belgium and the Netherlands, later via Norway and from Southern and Eastern Europe: prospectively also via import terminals for green molecules in Northern Germany. At the cross border point in Waidhaus, for example, the connection to the Central European Hydrogen Corridor project (see section 2.2.1) is established. The project, which will transport hydrogen from Ukraine via Slovakia and the Czech Republic to Germany, will land there and thus also contribute to the H_2ercules. The GET H2 network (see section 2.5.5) is also covered within the H_2ercules project. Concluding, the project contributes to the emergence of a European hydrogen market.

First companies have already signaled their interest in this project, and it is expected that in the future not only large consumers will benefit, but also smaller companies, thus leading the overall economy into a decarbonised future.

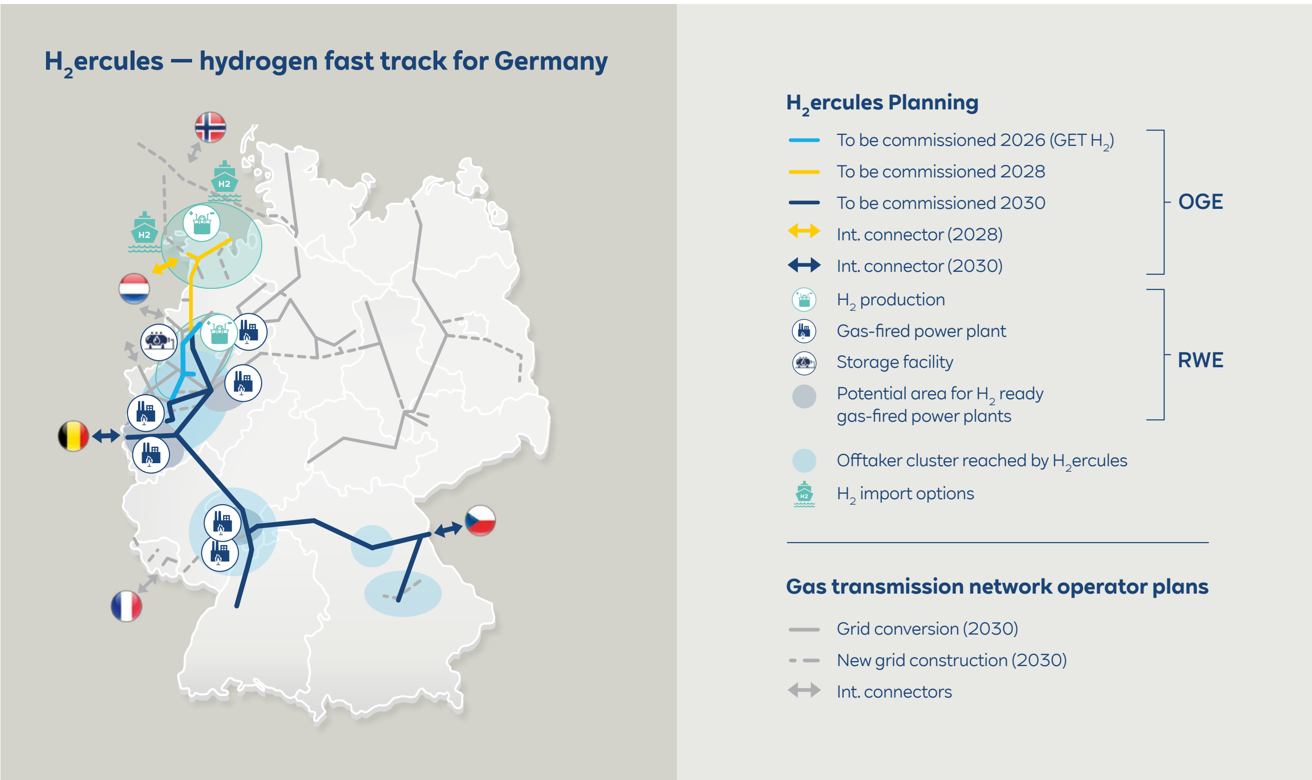


Figure 18: H_2ercules – hydrogen fast track for Germany (Source)

2.5.2 H2EU+Store

Green Hydrogen for Europe: Hydrogen from sun and wind will be produced in Ukraine and stored for seasonal demand in Central Europe in the future.

The initiative is structured as an integrated project by looking at the entire value chain (from production, transport and storage and including the consumer market) of the future hydrogen market.

Since renewable energy sources in the European Union are far from sufficient to transform the existing energy systems into climate neutrality, Member States of the European Union will have to import large quantities of hydrogen.

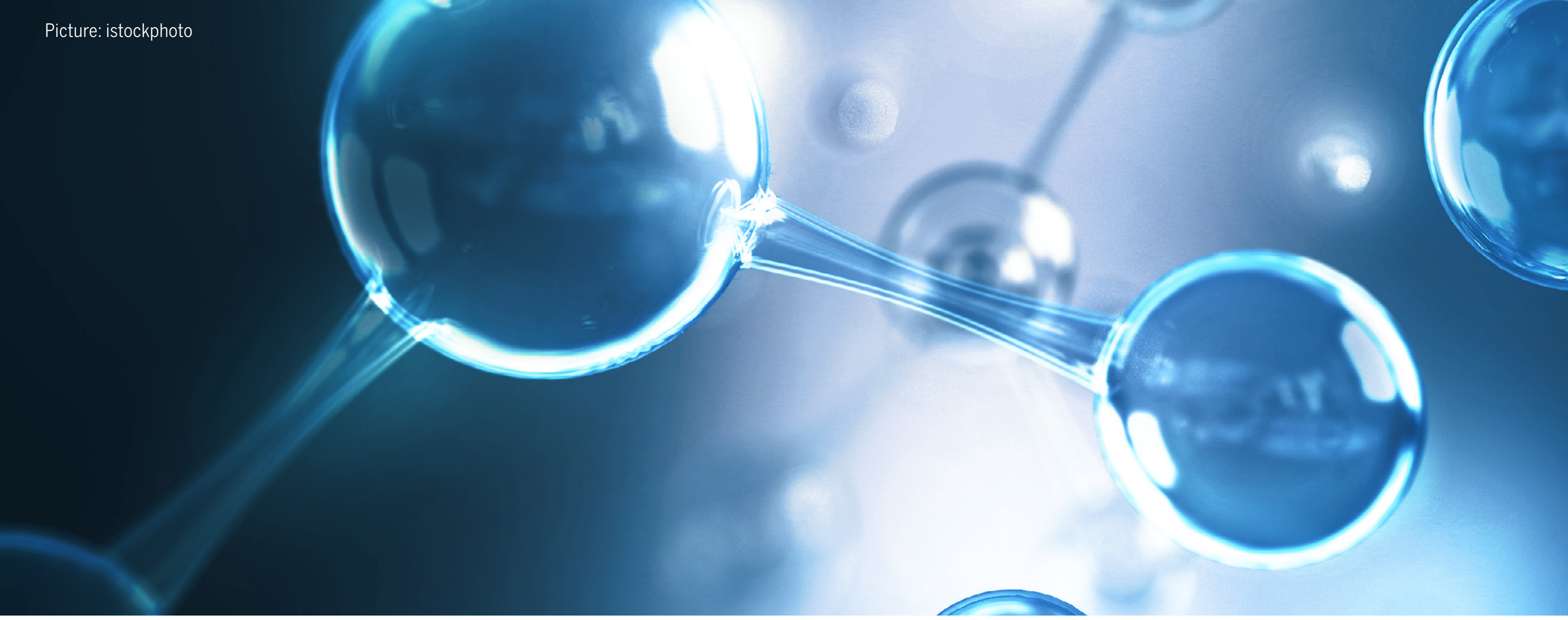
In onshore Europe, Ukraine offers the best conditions for large-scale, green hydrogen production. Ukraine combines enormous potential for electricity production from wind and sun and sufficient water resources with access to the existing international gas infrastructure for transporting hydrogen to Central Europe. This also is in line with the European Union's hydrogen strategy, in which Ukraine is seen as one of the primary partners for the hydrogen rollout.

The focus of "H2EU+Store" is on the one hand to ramp up and accelerate the production of green hydrogen in Ukraine to be prepared for a climate-neutral hydrogen supply to Central Europe. Therefore, the first step is to create the necessary foundation for renewable energy and hydrogen production in Ukraine.

In addition, the industry partnership "H2EU+Store" is pursuing the inevitable expansion of storage volumes (both for production balancing and to balance the seasonal demand) as well as adaptions in the area of gas transport from Ukraine to Central Europe. By using the existing supraregional gas transmission network for hydrogen transport, considerable time and cost savings can be achieved. Supplemented by new additional hydrogen pipelines and storage facilities, a highly efficient hydrogen network will be created. The midstream partners of H2EU+Store are ready to transport and store hydrogen. It is already possible to blend small quantities of hydrogen into the gas system. Following a corresponding hydrogen market ramp-up, dedicated hydrogen pipelines can be made available to customers from 2030 onwards.

The international industry partnership "H2EU+Store" consists of RAG Austria AG, Eco-Optima LLC, Bayerngas GmbH, bayernets GmbH, Open Grid Europe GmbH, Gas Connect Austria GmbH, Nafta, a.s. and eustream, a.s. The initiative is to be continuously expanded along the entire value chain in order to bundle forces and knowhow for the desired hydrogen ramp-up.

Figure 19: H2EU+Store (Source)



2.5.3 HyDeal Ambition

In February 2021 after 2 years of research and confidential preparation, a group of 30 pioneering European energy players officially launched "HyDeal Ambition" with the aim of delivering 100 % green hydrogen across Europe at €1.5/kg before 2030. The ambition is to achieve 95 GW of solar and 67 GW of electrolysis capacity by 2030 to deliver 3.6 million tonnes of green hydrogen per year to users in the energy, industry and mobility sectors via the gas transmission and storage network. A phased approach is anticipated with first deliveries in Spain and the Southwest of France followed by an extension towards the East of France and then Germany. A series of projects and partnerships are currently being launched involving several of the 30 participants of HyDeal Ambition, with a first initiative expected within a year in Spain, based on a portfolio of solar sites with a capacity of close to 10 GW.

OGE is the TSO initiator on the German side and is working on solutions to implement the transport needs that result from the H_2 deliveries and project milestones targeted by HyDeal Ambition. This is done in close cooperation with the TSOs from Spain, France and Italy in order to design the entire transport chain in the project across Europe and across borders. In this context HyDeal ambition contributes significantly to the development of the "European Hydrogen Backbone", a concept developed by European TSOs for the gradual development of a Europe-wide and non-discriminatory H_2 network. The TSOs supported the analysis done within HyDeal Ambition, investigating means to transport the green hydrogen in the most efficient manner from the locations of production to the demand centers across Europe.

The transport of large volumes of green hydrogen to Germany is a corner stone in HyDeal Ambition as more than 1/3 of the total volumes are expected to be delivered to industrial customers in Germany which are very interested in green hydrogen at competitive prices.

According to initial planning, the transport of the H_2 in Germany could be carried out mainly by repurposed natural gas pipelines, supplemented by infrastructure to be built. This will enable H_2 transport from the German-French border to central and southern Germany as well as to North Rhine-Westphalia (NRW), where a connection to the H_2 network as planned within the GET H2 project (see section 2.5.5) is possible.

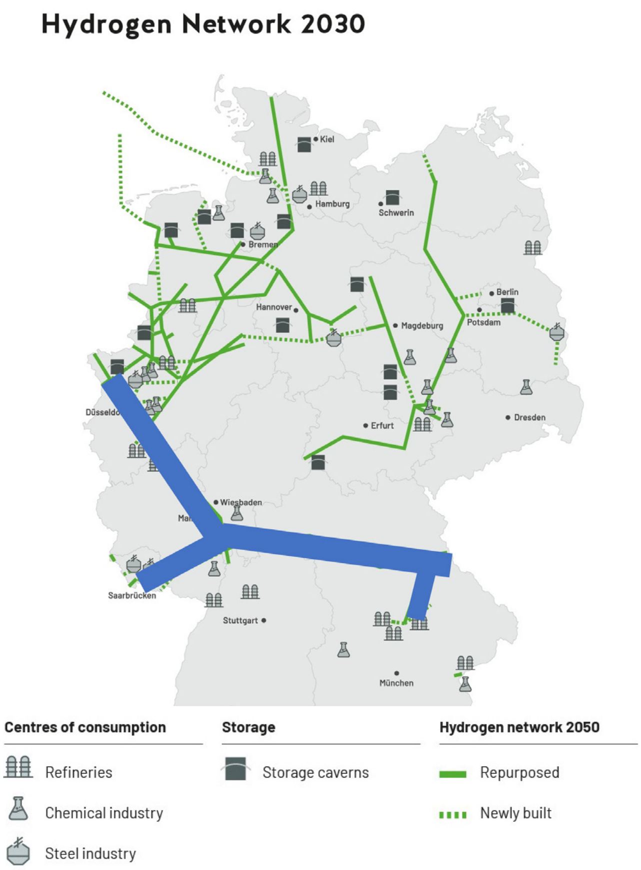
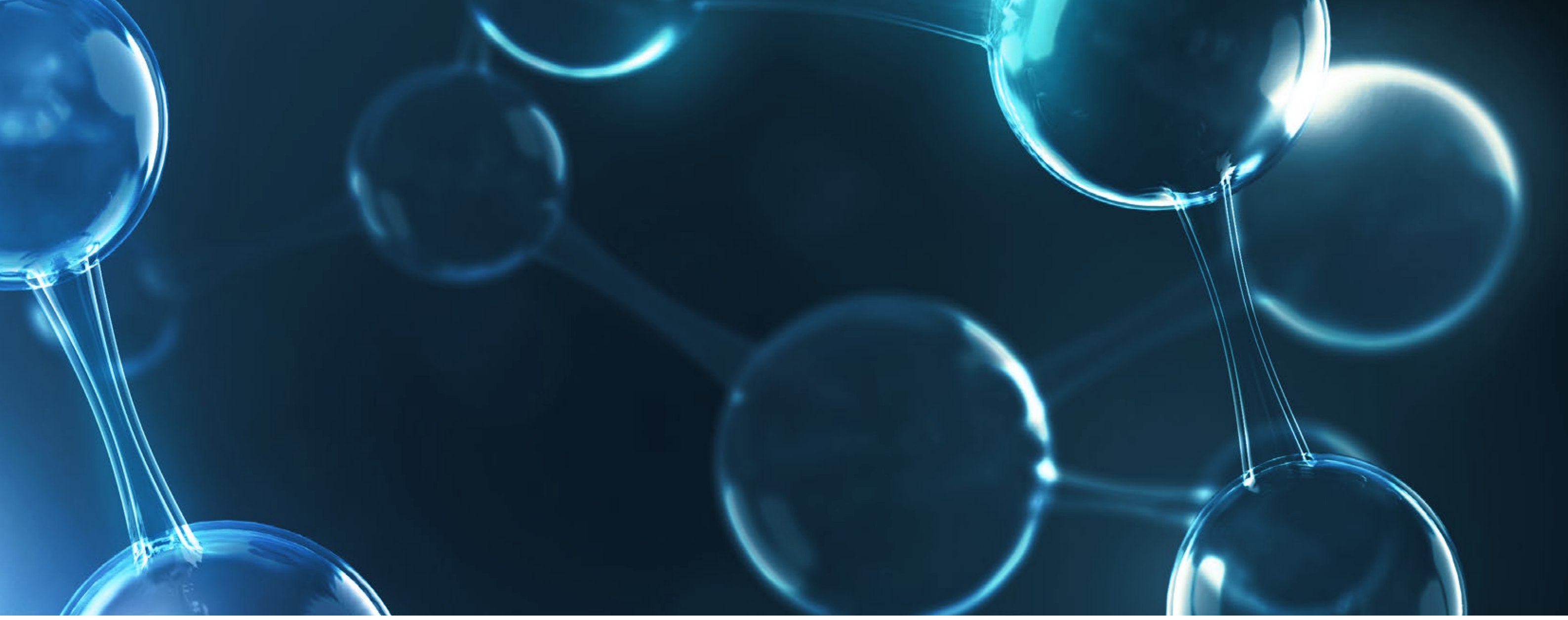


Figure 20: Schematic representation of the envisaged pipeline sections (blue) in the Hydrogen Network 2030 of the FNB Gas



2.5.4 Low Carbon Energy Hub

For the transition of its energy system Germany will require imports of green and blue hydrogen from auspicious sources such as Norway. The project study Low Carbon Energy Hub (LCE Hub) focuses on both, the large-scale climate friendly production of hydrogen as well as the pipeline transport from Norway.

The companies participating in the LCE Hub include Equinor, Gassco and OGE. Equinor looks into hydrogen production in Norway, Gassco into pipeline transport of hydrogen into the EU. OGE plans to create a Germany-wide, publicly accessible hydrogen network.

Besides the potential new-build of dedicated hydrogen pipelines, one option for hydrogen export from Norway is to use at least partly existing natural gas pipelines that can be repurposed to transport pure hydrogen.

In a transition phase, blending hydrogen into natural gas might be a first step towards a dedicated hydrogen transport infrastructure. Thus, the project also considers how to extract hydrogen from the blends, how to handle natural gas blends in the midstream pipeline network, control its level of hydrogen and to protect sensitive end users. Also, offshore windfarms have expressed interest in connecting to the Norwegian gas pipelines to inject green hydrogen into the current natural gas stream. For the avoidance of doubt, OGE will not be involved in the production. Equinor and Gassco will not be involved in downstream de-blending of hydrogen. However, both Equinor and Gassco support the project with relevant information on the upstream boundary conditions to facilitate design optimisation.

2.5.5 GET H2

GET H2 is the name of an initiative for the implementation of a nationwide H_2 infrastructure in Germany.

Germany has set for itself the target of reducing CO_2 emissions by 80–95 % (compared to 1990). In order to achieve this goal with the greatest possible efficiency, utilisation of hydrogen is required alongside the expansion of renewable energy generation and electricity infrastructure. The conversion of electricity generated by renewable energies into H_2 – Power-to-Gas – is, as such, key to a successful energy transition.

The key concept is as follows:

- Electricity from renewable energy (wind and solar) is converted into H_2
- H_2 is transported using the pipelines converted from the existing gas transmission network
- In the industrial, transport, energy and heating sectors, green H_2 is used as a CO_2-free source of energy
- H_2 that is not used directly can be stored in underground caverns, especially for phases where renewable energy is not available

GET H2 connects regions with a high potential for renewable energy generation from e.g., wind and solar power, to industrial-scale consumers of H_2. Furthermore, GET H2 aims to develop a nationwide H_2-infrastructure. Such infrastructure will link all sectors and make the best possible use of the existing natural gas transmission network and storage facilities as well as the electricity grid. This way, the initiative also solves the problem of supplying renewables during dark doldrums and in the winter months.

More than 50 project partners support GET H2 (the full list is accessible here).

GET H2 Nukleus: Kick-off from Lingen to Gelsenkirchen

As part of the project GET H2 Nukleus the first publicly accessible H_2-infrastructure will be operational in 2024. The approximately 130-kilometer-long network from Lingen to Gelsenkirchen connects the production of renewable H_2 to industrial customers in Lower Saxony and North Rhine-Westphalia, thus creating the basis for a hydrogen economy in Germany.

- Electricity from renewables
- Power-to-Gas plants (electrolysis) to produce renewable H_2
- Existing electricity and gas infrastructures including gas storage facilities
- Supply of H_2 to refineries and chemical parks for use in production processes, including initial applications for the transport sector if necessary

Project partners of GET H2 Nukleus are BP, Evonik, Nowega, OGE and RWE.

GET H2 IPCEI: Extension to the Netherlands

Based on the GET H2 Nukleus project, the pipeline network will be extended by 2025 to the Netherlands utilising converted pipelines. By 2026 a salt cavern storage and additional connections to industrial consumers in Duisburg-Hamborn will be connected to the hydrogen pipeline network.

Project partners of GET H2 IPCEI are the project partners of GET H2 Nukleus complemented by RWE Gas Storage West and Thyssengas.

2.5.6 doing hydrogen – The Eastern German Hydrogen Hub Is Coming

This is where hydrogen makes the energy transformation possible. Doing hydrogen connects H_2 projects in Mecklenburg-Western Pomerania, Brandenburg, Berlin, Saxony and Saxony-Anhalt to form a high-performance hub: production, transport, storage and consumption of this raw material of the future all under one roof, ready to launch in 2027. A unique project for the people and economy in eastern Germany – an important building block in implementing the German and European hydrogen strategy.

IPCEI project: doing hydrogen transmission system

Doing hydrogen marks the launch of a platform for the hydrogen economy in eastern Germany, in collaboration between ONTRAS Gastransport GmbH and GASCADE Gastransport GmbH. The hydrogen transport system will provide the connecting element: the project partners are creating a 616-km long pipeline system between the economic regions of central Germany and the Rostock region as well as the greater Berlin area and Eisenhüttenstadt. This will be used to link together hydrogen projects in Mecklenburg-Western Pomerania, Brandenburg, Berlin, Saxony and Saxony-Anhalt to form an efficient hub. Prospective extension of the pipeline network towards Poland is envisaged.

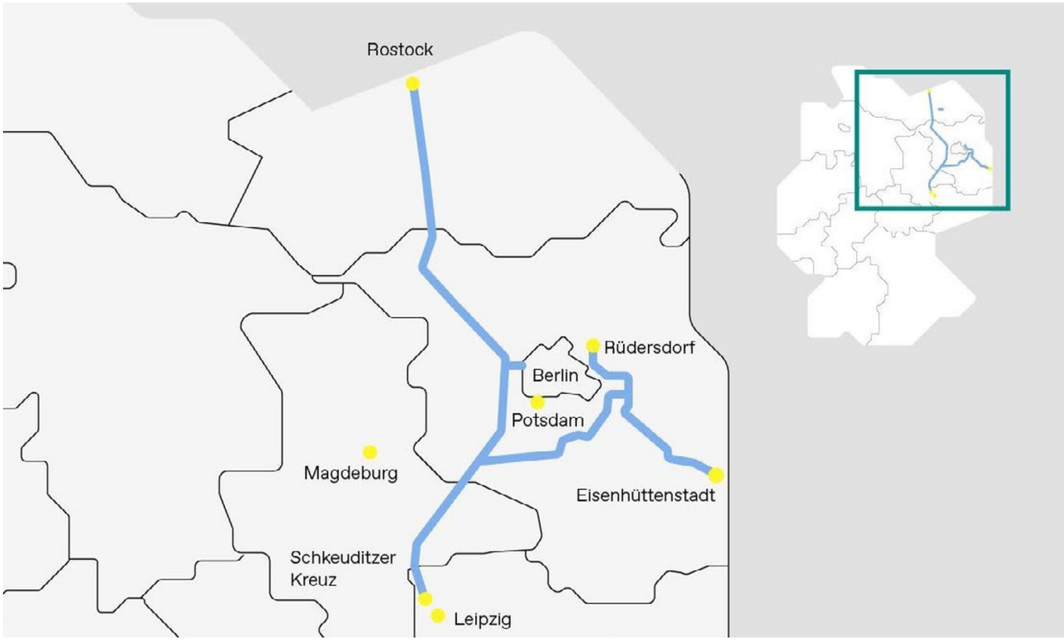


Figure 21: Infrastructure of doing hydrogen (Source: ONTRAS Gastransport GmbH)

ONTRAS and GASCADE are also the two companies that launched doing hydrogen. As the initiators, they are instrumental in building a strong platform for the hydrogen economy in eastern Germany.

doing hydrogen is one of the projects that have been selected by the Federal Ministry of Economic Affairs and Technology as IPCEI (Important Projects of Common European Interest) in 2021.

2.5.7 Green Octopus Mitteldeutschland – Green Hydrogen for Industrial Regions

The Central German Chemical Triangle needs green hydrogen. The same is true for the industries in Saxony-Anhalt and the steel region in Salzgitter/Lower Saxony. Green Octopus Mitteldeutschland (GO!) is the future transport route for this hydrogen: GO! connects the regions and integrates the future hydrogen storage facility in Bad Lauchstädt.

IPCEI project GO! connects regions

From 2027, GO! will ensure the secure transport of hydrogen between the Central German Chemical Triangle, the metropolitan area of Halle–Leipzig, Magdeburg and the steel region in Salzgitter with a network of pipelines covering around 305 km. GO! will also make use of other H_2 pipelines to integrate these regions into the growing European Hydrogen Backbone. A connected cavern storage facility provided by VNG Gasspeicher GmbH with a working gas volume of 50 million cubic metres stabilises the hydrogen infrastructure and ensures a balance between supply and demand.

Towards the north, GO! will extend to the Salzgitter industrial area in Lower Saxony, where it can be connected to the planned pipeline infrastructure extending to the North Sea and Benelux. This creates security of supply, particularly for the high demands of the steel industry. GO! also enables the flexible arrangement of other supply and delivery points for hydrogen along the catchment area of the entire route, which will support the establishment of new hydrogen producers and consumers. In the south, GO! branches out into three lines from the end point of the H_2 pipeline at the Energiepark Bad Lauchstädt in Leuna. They cover greater Leipzig in the north and south.

Along with doing hydrogen, GO! is one of the ONTRAS projects that has been selected by the Federal Ministry of Economic Affairs and Technology as IPCEI (Important Projects of Common European Interest) in 2021.

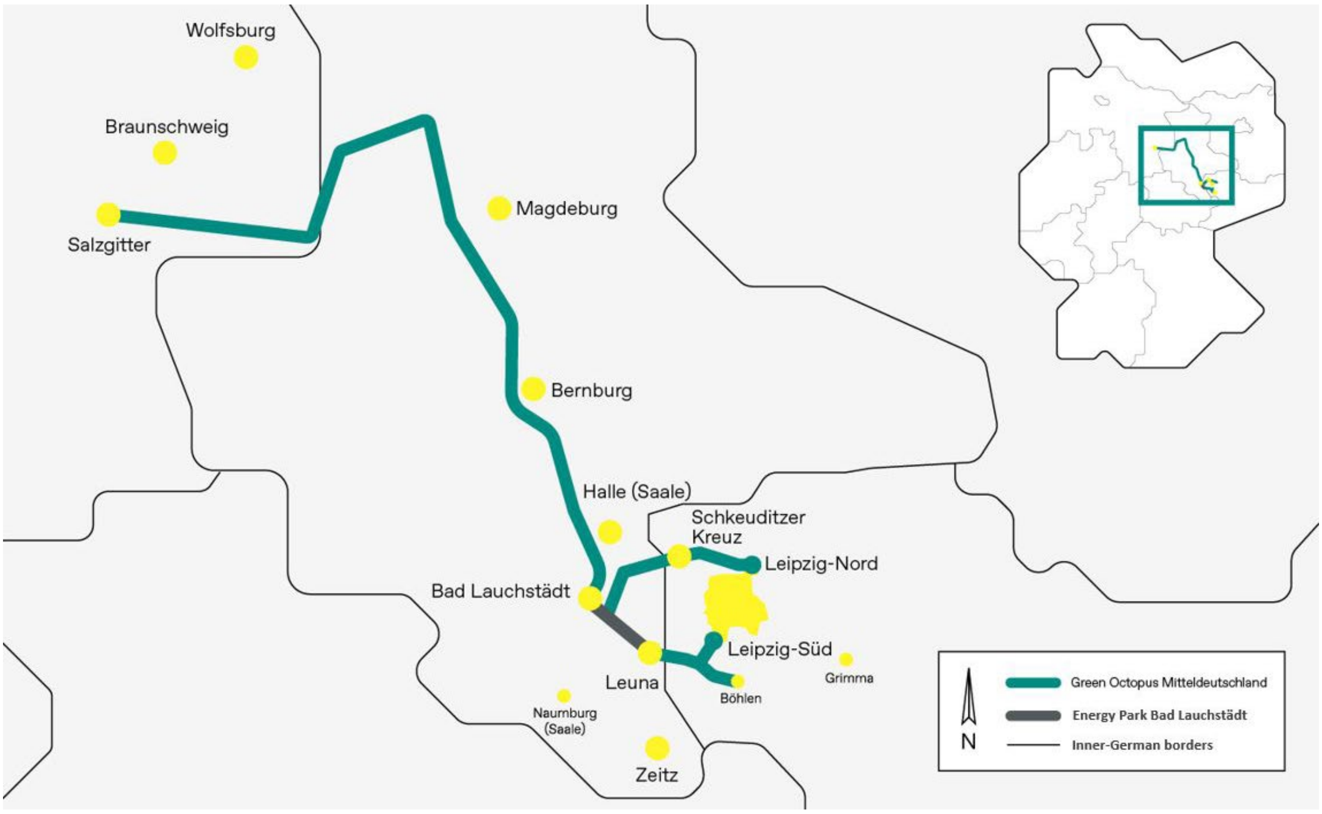


Figure 22: The pipeline infrastructure of Green Octopus Mitteldeutschland (GO!)

2.5.8 Nordic-Baltic Hydrogen Corridor

Using the significant potential for the production and use of hydrogen in countries surrounding the Baltic Sea, the Nordic-Baltic Hydrogen Corridor aims at developing a cross-border hydrogen infrastructure from Finland to Germany, via Estonia, Latvia, Lithuania and Poland. The participating companies are GASGRID (TSO of Finland), Elering (TSO of Estonia), Conexus Baltic Grid (TSO of Latvia), Amber Grid (TSO of Lithuania), GAZ-SYSTEM (TSO of Poland) and ONTRAS (a leading German TSO).

The infrastructure of the Nordic-Baltic Hydrogen Corridor would enable the achievement of ambitious hydrogen targets set out in the REPowerEU Plan and to support European energy independency, achievement of climate neutrality goals as well as creation of investments and jobs in the region. It will make full use of domestically produced hydrogen and will supply it to demand centres along the corridor as well as to central Europe. The foreseen capacity of the infrastructure is 200 GWh/d for transportation of hydrogen from the Baltic region to central Europe and 100 GWh/d for the transportation in the opposite direction. The initial phase will comprise a feasibility study for establishing the hydrogen corridor. The second phase will be the construction of hydrogen corridor (high-pressure pipelines and ancillary installations) initially intended to be taken into use by the end of 2029.

2.5.9 Clean Hydrogen Coastline – ELEMENT EINS

Plenty of renewable energy, existing infrastructure, a strong economy with lots of operational scenarios and direct links to other markets via land and sea: Germany's north-west has everything it needs to integrate hydrogen technology into the German and European energy system to a meaningful extent – not just as a starting point, but as a mainstay of an international hydrogen economy with huge potential for scaling up.

Several projects have already addressed the region for an initial integration and a subsequent market ramp up of hydrogen technologies. To support an effective market integration, project partners of Clean Hydrogen Coastline and ELEMENT EINS have joint forces in 2021.

The Clean Hydrogen Coastline project combines several projects with the joint aim of a fast and effective market ramp-up of a hydrogen economy. This means that hydrogen production, distribution, use, supply and demand are being increased at the same time. Partners of Clean Hydrogen Coastline are ArcelorMittal Bremen, EWE, FAUN, swb and TenneT. Hydrogen infrastructure aspects for production, storage and distribution of Clean Hydrogen Coastline are aiming for public support as Important Project of Common European Interest (IPCEI).

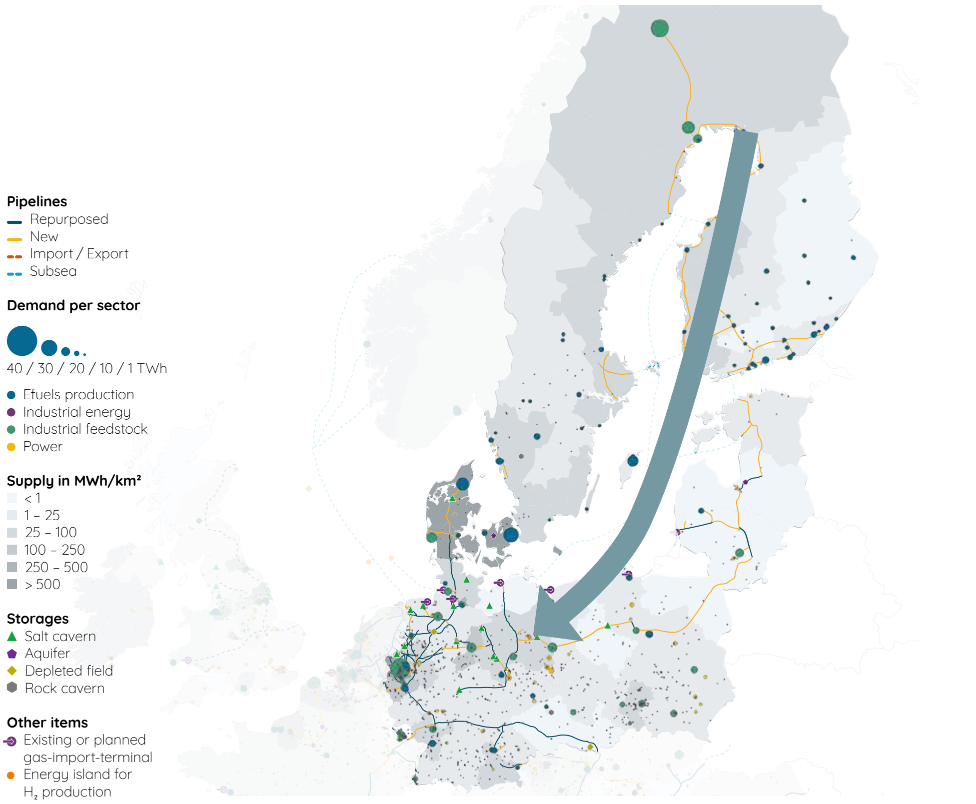


Figure 23: Nordic-Baltic Hydrogen Corridor (Source: European Hydrogen Backbone report)

With ELEMENT EINS, the German gas TSOs Gasunie Deutschland and Thyssengas together with the TSO for electricity, TenneT have been pursuing the concept of an industrial power-to-gas plant in the 100-megawatt class since October 2018, in order to convert electricity from renewable energies into green hydrogen. As part of a feasibility study, East Frisia has already been identified as a suitable location for the electrolyser. This location could be confirmed in the hydrogen study "Quo vadis, electrolysis?" as one of three ideal initial locations for starting the construction of infrastructurally coupled electrolysers from a systemic point of view.

By Power-to-Gas technologies, sustainable electricity can be converted into gas (green hydrogen or synthetic methane). Existing gas infrastructure can thus be used for the transport and storage of renewable energies. Power-to-Gas can make a significant contribution to solve the problem of the weather-dependent and thus volatile availability of renewable energies, as well as the transport of huge amounts of electricity. The ability to store large volumes of renewable electricity will reduce the load on the power grid significantly.

From 2022 to 2027, the project Clean Hydrogen Coastline will connect electricity and gas grids, offering new storage capacities for renewable energies. Therefore, up to 370 megawatt of electrolysis capacity will be integrated with a systemic approach at the locations of East Frisia and Bremen. Gas that has been converted from green energy will be transported from the North Sea to the industry areas of Bremen and Hamburg through existing pipelines. The hydrogen produced from renewable will be available for several customers in the industry and mobility sector.

By the integration of a large-scale underground storage facility, Clean Hydrogen Coastline will provide energy supply security for customer applications. In combination with systemic operation of the electrolyser, flexibility can be provided for the electricity system as well. With a direct connection of the storage location to the European Hydrogen Backbone, storage capacities can be offered in an open-access approach to several customers.

While Clean Hydrogen Coastline will address concrete investment projects for an initial hydrogen infrastructure, partners of ELEMENT EINS will focus on the strategies for further market ramp up in the North-West region.

In combination, Clean Hydrogen Coastline and ELEMENT EINS will support the introduction of the North-West region towards an important pillar of a European Hydrogen Economy.

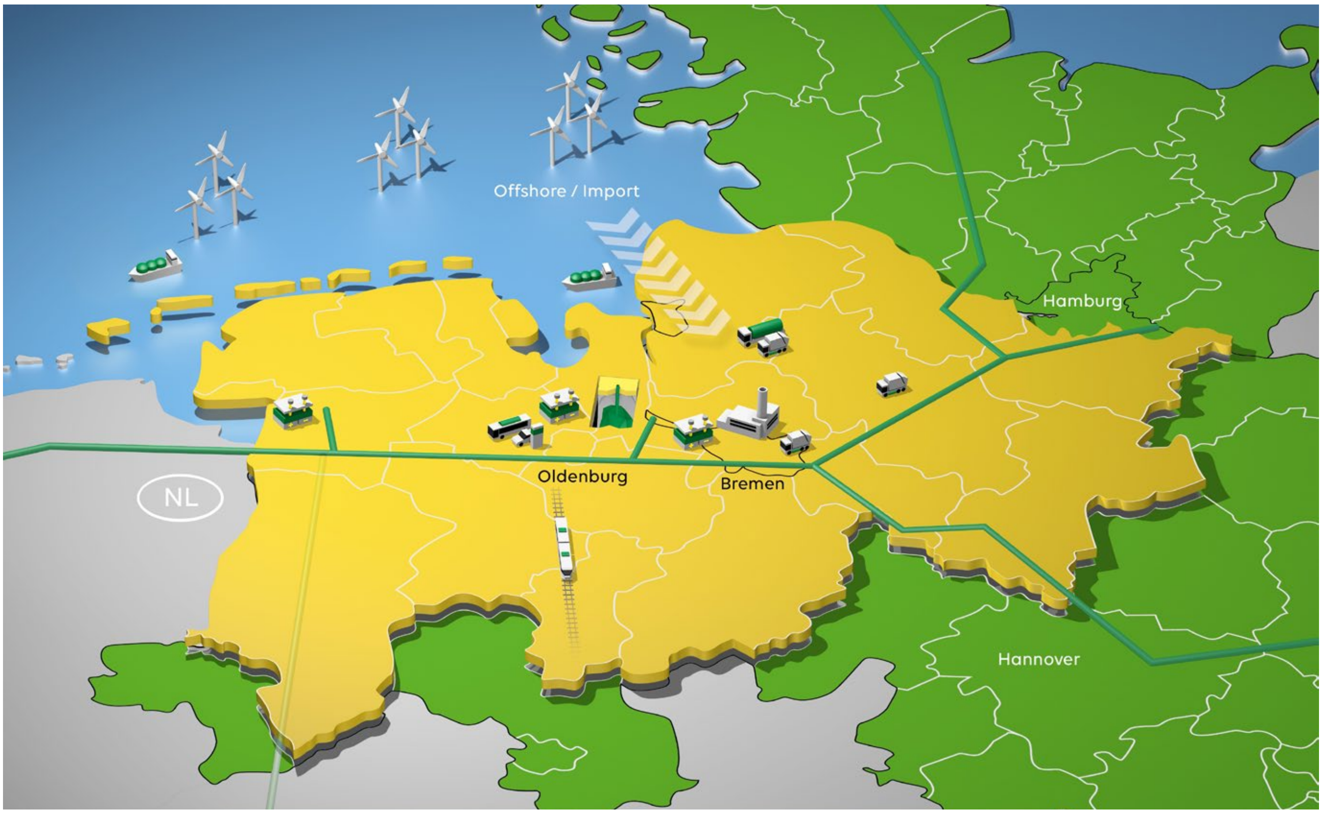


Figure 24: Projects Clean Hydrogen Coastline and ELEMENT EINS (Source: EWE AG)

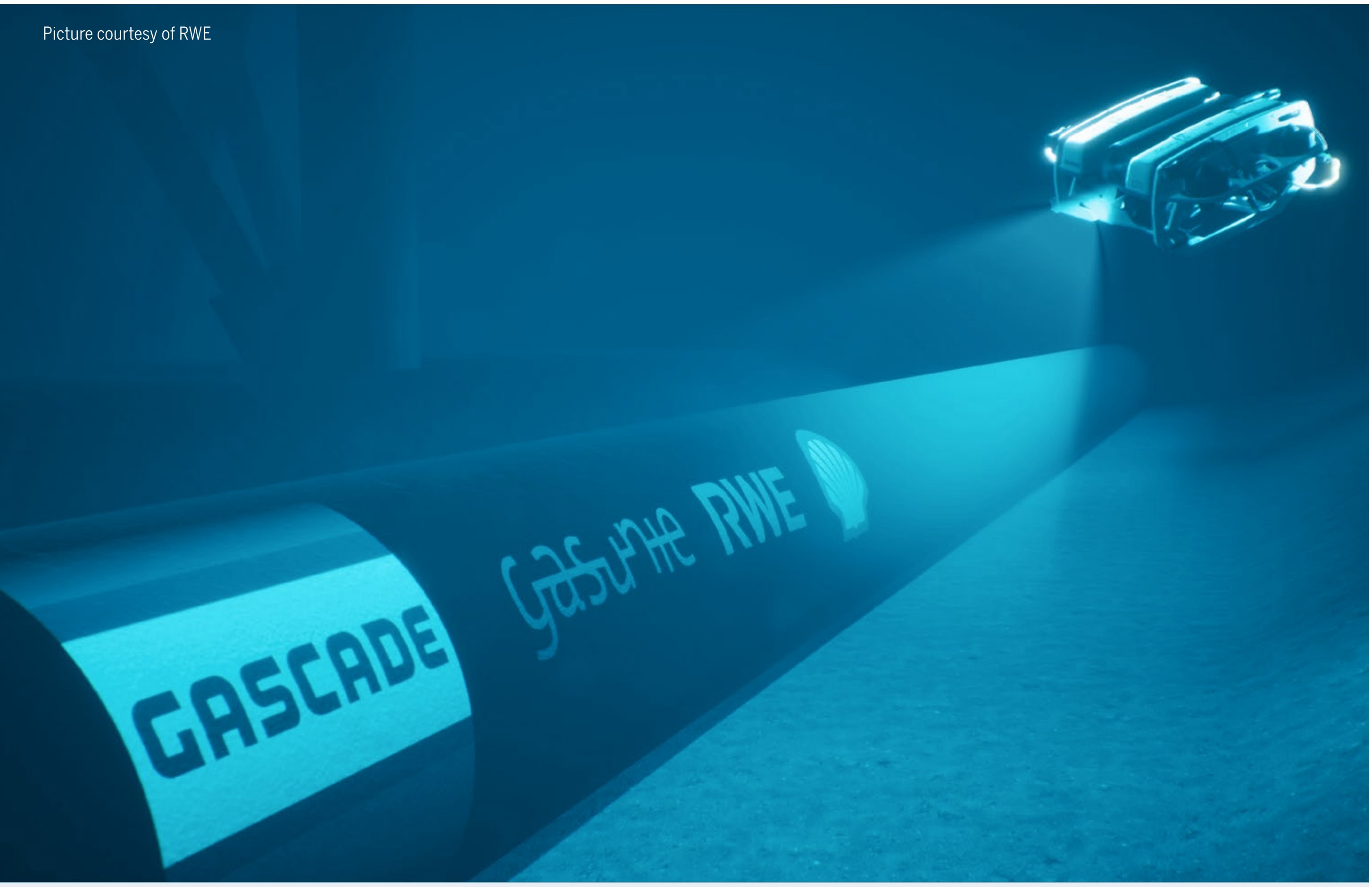
2.5.10 AquaDuctus

The AquaDuctus pipeline is the concept of the first German offshore hydrogen pipeline which will transport green hydrogen from the North Sea directly to the mainland. AquaDuctus is a cooperation of European TSOs and Energy Companies.

The project is divided into successive phases, the first of which is scheduled to start in 2023.

In a first phase, a small offshore hydrogen production plant (AquaPrimus2) with a capacity of 14 MW off the coast of Helgoland will be connected to the island. These projects were selected by the German Federal Ministry of Economics for funding as part of the hydrogen IPCEI process with GASCADE being the applicant for AquaDuctus. The next step is to connect the SEN-1 wind farm site, 150 km northwest of Heligoland, with a generation capacity of over 300 MW to produce green hydrogen to the German mainland and the pursuing onshore hydrogen infrastructure. It is planned to design the pipeline in such a way that a connection can be established to future hydrogen wind farm locations in the German exclusive economic zone of the North Sea, and connections to European countries bordering the North Sea can also be established via this.

Once the generation plants are fully developed, AquaDuctus is expected to transport in German waters up to one million tons of green hydrogen per year from 2035 onwards, thus making a substantial contribution to decarbonizing the energy supply in Germany and Europe.



Picture courtesy of RWE

2.6 IRELAND

2.6.1 Sustainable Renewable Gas Central Grid Injection Project

The Sustainable Renewable Gas Central Grid Injection Project by Gas Networks Ireland (GNI) involves the construction of two Central Grid Injection (CGI) facilities for injecting renewable gas into the gas network. Biogas produced at local Anaerobic Digestion (AD) plants will be upgraded to renewable gas (biomethane) and transported by road to the CGI facilities for injection into GNI's transmission system. The two CGI facilities will enable the cost-effective injection of biomethane without constraint from circa 40 new Anaerobic Digestion plants for whom a direct pipeline connection is considered to be either economically or technically not viable. The first transmission connected CGI facility is being developed in Mitchelstown, Co. Cork as part of the GRAZE (Green Renewable Agricultural & Zero Emissions) gas project. This project has been shortlisted for grant funding support from the Irish Government's Climate Action Fund and planning consents for the project have been achieved. The exact location of the next CGIs has not yet been finalised.

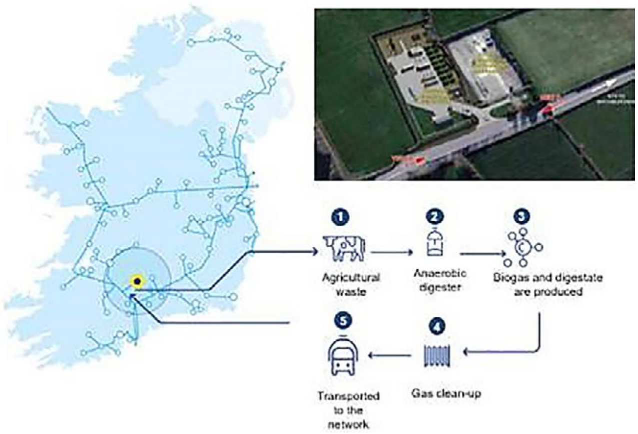


Figure 25: Overview of Centralised Grid Injection Concept, G as Networks Ireland

2.6.2 Brownsbarn Networks Innovation Centre

Gas Networks Ireland is developing a Networks Innovation Centre in West county Dublin, adjacent to their Brownsbarn Above Ground Installation site. This facility is independent of the gas network and will use certified blends of natural gas and hydrogen for the purposes of assessing the compatibility of elements of the network and appliances typically used in Ireland. The facility will be able to begin the process of evaluating aspects of the network that are particular to Ireland and provide an opportunity for Gas Networks Ireland staff and stakeholders to gain experience of different hydrogen blends.

Figure 26: Picture of Networks Innovation Centre, Gas Networks Ireland

2.7 THE NETHERLANDS

2.7.1 Hydrogen backbone

The hydrogen backbone in the Netherlands[26] is a nationwide network that, combined with region networks will connect hydrogen demand with production and storage locations of hydrogen. A first part is already operational (since October 2018): a pipeline connecting the industrial facilities of Dow and Yara in Zeeuws Vlaanderen.

In follow up phases a gradual expansion of the hydrogen network will be realised. Part of the network currently carrying natural gas will converted to transport H_2. Keeping pace with increasing H_2 transportation demand the regional networks and national backbone will be developed. In later stages to backbone can be extended to facilitated both international H_2 transport as well as an off shore grid enabling transport. Thereby facilitating the onshoring of energy from sea based windfarms.

Among the projects that could profit from the backbone are:

- **The North Sea Wind Power Hub:** An opportunity for internationally coordinated, large scale, far offshore wind energy from the North Sea. An opportunity which would deliver energy at competitive prices by approximately 2030 and thus facilitate Europe meeting the targets of the Paris Agreement. The Netherlands is committed to exploring and developing regional socio-economic beneficial and reliable offshore infrastructure, including possible conversion into Power-to-Gas that supports wind farm operations and interconnections between markets.
- **Djewels:** The project is a significant step towards scaling up the electrolysis technology, (co-) develop, own and operate a large-scale electrolyser, offering conversion services (electricity to hydrogen) to market parties, contribution to the development of a hydrogen economy in (North-) Netherlands, particularly in the chemical industry and mobility sector.
- **ACE Terminal:** Gasunie and partners are developing an import terminal for green ammonia as a carrier for hydrogen. ACE Terminal will be built on the Maasvlakte and is expected to be ready early 2026
- **HyStock:** HyStock is working on the first large-scale underground storage of hydrogen in the Netherlands using salt caverns

26 https://www.dewereldvanwaterstof.nl/longread-hydrogen/infrastructure/

Figure 27: Overview Energy transition projects in the Netherlands (Source: Gasunie)

2.7.2 Carbon capture

Carbon capture, utilisation and storage (CCUS) is a technology that offers significant reductions of carbon emissions. The IPCC states that CCS is a key to reaching net-zero emissions by mid-century and mitigating climate change. In the Netherlands three projects are under development, the Porthos project, the CO2next project and the Aramis project, all in the Rotterdam area. At the end of 2021 the Dutch subsidy system for renewable energy was also opened for CCS projects. CCS is a relatively cost-effective means to reduce CO_2-emissions, and can quickly achieve large reductions.

Porthos

The initiators of the Porthos (Port of Rotterdam CO_2 Transport Hub and Offshore Storage) project are the Port of Rotterdam Authority, Energie Beheer Nederland B.V. (EBN) and Gasunie. These companies are working on the construction of a CO_2 transport and storage infrastructure between the Port of Rotterdam and depleted gas fields beneath the North Sea. Some of the CO_2 can be used in the South Holland greenhouses to ensure faster plant growth. The total length of the CO_2 infrastructure is around 55 km. The storage will take place in the P18 fields, 21 km off the Dutch coast.

Port of Rotterdam Authority, EBN and Gasunie are three organisations that play an important role in the Dutch energy landscape. In this project, each external organisation offers specific experience and expertise. Port of Rotterdam Authority with its knowledge of the local situation and market, EBN with its expertise of the deep subsurface and Gasunie as gas infrastructure and transport expert. Porthos has been granted Project of Common Interest (PCI) status by the European Commission. A PCI project is an energy infrastructure project that has obtained preferred status on behalf of the European Commission. This also means that permit applications are more streamlined and the applications are made simultaneously as one total package of permits.

CO2next[27]

Initiators of the CO2next project are Gasunie, Vopak and GATE terminal. In this project a liquid CO_2 terminal in Rotterdam would be developed. This terminal will be able to receive and deliver liquid CO_2 via ships and will be connected to the depleted gas fields in the North Sea, offering transport for substantial volumes of CO_2 in the near future. With an open access system this would make the necessary infrastructures available to all market parties, including parties that do not have a direct connection to a CO_2 pipeline. Functionality for additional services is envisaged such as re-loading and transhipment of CO_2. Thus, this planned terminal can also be an important catalyst in the creation of a market for the reuse of CO_2 as a raw material.

Aramis[28]

Parties in the Aramis project are Total Energies, Shell Nederland, EBN and Gasunie. Aramis is developing large scale CO_2 infrastructure to bring CO_2 from industries to offshore empty gas fields in the North Sea. Its starting point would be Rotterdam, with a hub encompassing a compressor station, storage tanks with liquid CO_2 and a terminal for ships. The offshore pipeline would be around 200 km. Intention is to create synergy with the other existing CCS projects, Porthos and CO2next. Aramis has been granted PCI status by the European Commission.

Figure 28: Overview of the Porthos project (Source)

27 https://co2next.nl/
28 https://www.aramis-ccs.com/

2.7.3 Biomethane

Biomethane substantially contributes to CO_2 reduction on short and medium term (2030 and earlier). Fermentation, gasification and super critical water gasification all have a role in achieving the 2 bcm biomethane target for 2030. The decision to introduce a blending obligation for biomethane will further boost biomethane production. Investigations have been started to speed up biomethane production, resulting in additional bcm's of biomethane production by 2030.

Biomethane from fermentation mainly results from multiple smaller scale fermentation projects. The produced biogas volumes are only partly upgraded into biomethane and injected into the gas networks. Production of biomethane by gasification and super critical water gasification is done on a much larger scale.

Supercritical water gasification

Supercritical water gasification (SCWG) is an innovative technology that produces carbon neutral gasses from organic residual flows containing hydrocarbons. This includes residual flows from natural source as well as waste flows. Even wet biomass like manure, green waste and sewage sludge can be handled. SCWG is a so called thermo-chemical conversion technology, cracking organic molecules in the biomass material under supercritical conditions producing biogas (methane, hydrogen, CO_2 and CO). The SCWG process shows a high efficiency and delivers biomethane at high pressure which can be injected in the nearby high-pressure gas transmission grid without further compression.

Gasunie and SCW Systems are working together to further scale up this innovative technique, which has already been demonstrated to function on industrial scale. In 2022 the first installation is expected to become operational. In the following years additional installation will become operational. The pace of this upscaling will amongst others depend on the lessons learned from operating the first plant, and the need to replace possible gas delivery disruptions from Russia.

Gasification

The Torrgas project is a gasification project heading for production of biomethane in 2024. Gasunie and Perpetual Next will start the construction of an industrial plant in Delfzijl in the second half of 2022. The plant will use renewable feedstock like organic residual flows, green waste and woody biomass to produce syngas via the torrefaction-technique. This syngas will be used in chemical applications or will be converted into biomethane, methanol or hydrogen. The first phase of this project will target the production of biomethane for injection into the existing gas grids.

2.7.4 Heat and Heat transport networks

The Dutch Ministry of Economic Affairs and Climate Policy has appointed Gasunie to develop the first phase of the heat transmission grid WarmtelinQ in South Holland[29]. WarmtelinQ will have a capacity of approximately 250 MW. The main trunk line will run from Rotterdam to The Hague. The heat is to be delivered to greenhouses, businesses and households in the Rotterdam/The Hague region, reducing CO_2 emissions by 0.18 Mton per year. Approximately 120,000 households will receive heat from WarmtelinQ. Early 2022 construction has started. Start of operation is planned for 2025. An extension towards Leiden is under consideration, adding another 50,000 households.

WarmtelinQ is part of a greater concept, called the Integral Design South Holland[30]. The industries based in the Rotterdam harbour area can provide enough heat for about 500,000 households and most of the nearby greenhouses. The heat it provides to these consumers will replace existing gas fired heating and will contribute to the national climate goals.

In other parts of the Netherlands potential for the use of geothermal and residual heat exists too, but projects are less far developed. In total there is a maximum potential for geothermal and residual heat in the Netherlands of up to 75 PJ in 2030 and up to 190 PJ in 2050[31].

29 https://www.warmtelinq.nl/

30 https://www.warmtelinq.nl/uploads/fckconnector/1cd481f5-b5d3-5881-8ba1-d6ecdc18c4f4, summary https://www.warmtelinq.nl/uploads/fckconnector/fdc76818-86ed-5506-b51c-7671f5451fb9

31 https://www.klimaatakkoord.nl/binaries/klimaatakkoord/documenten/publicaties/2019/01/08/achtergrondnotitie-gebouwde-omgeving-duurzame-warmte-en-duurzame-gassen/Gebouwde+omgeving+-+Vraag+en+aanbod+duurzame+warmte+en+duurzame+gassen.pdf

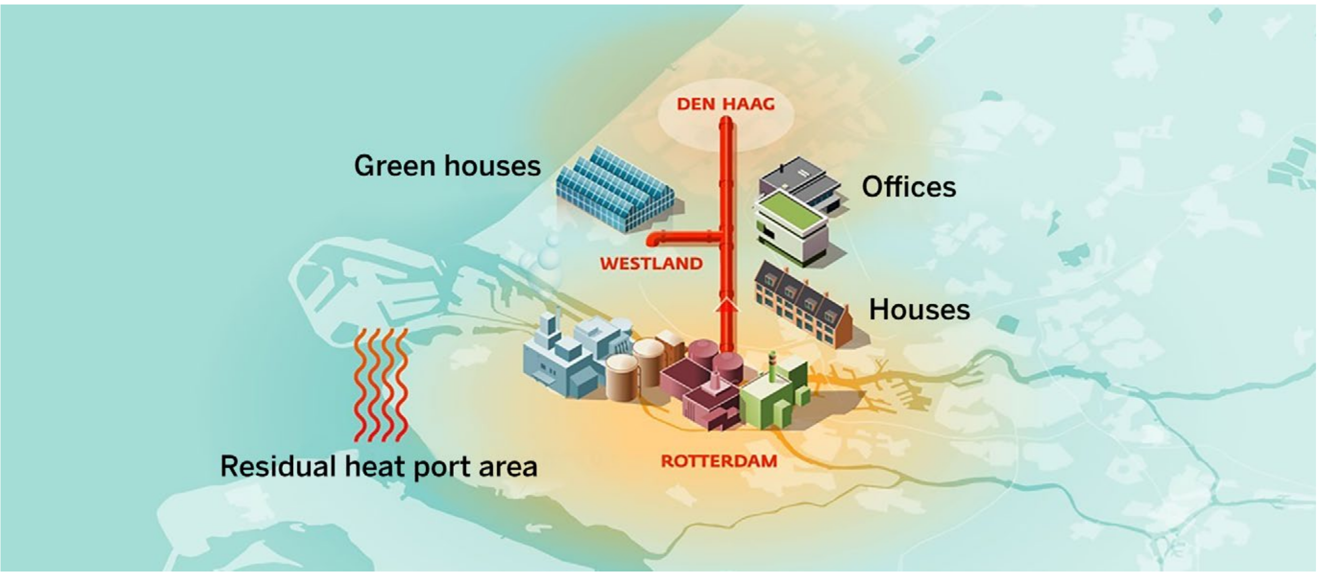


Figure 29: The WarmtelinQ project (Source)

2.8 SWEDEN

2.8.1 Nordic Hydrogen Route

Nordic Hydrogen Route is an initiative between Gasgrid Finland and Swedegas to drive decarbonisation, support regional green industrialization, economic development, and European energy independence. By building-up a cross-border hydrogen infrastructure in Bothnian Bay Region and an open hydrogen market by 2030, Nordic Hydrogen Route will accelerate the creation of hydrogen economy and new investments to support European energy transition and increase the access to green and competitive domestic energy.

Figure 30: Overview of the Nordic Hydrogen Route project

Nordic Hydrogen Route in numbers

- 1,000 km of new, dedicated hydrogen pipelines will serve 65 TWh of identified potential hydrogen demand in the Bothnian Bay region by 2050, across existing and emerging industries. The core route will be along the coastline, with a branch to Kiruna.
- The first sections of the pipeline network are expected to be operational by 2030.
- The pipelines will transport hydrogen produced from abundant wind resources – utilising excess or dedicated generation from up to 48 GW of wind capacity in the Bothnian Bay region by 2040.
- The Nordic Hydrogen Route investment is estimated at 3.5 B EUR/36 B SEK, offering a hydrogen transportation cost of 0.1–0.2 €/kg.
- The pipeline would enable ten-fold investments around 37 B EUR/380 B SEK in wind power and electrolysis, in addition to other investments along the hydrogen value chains.

- The pipeline network could transfer energy to hydrogen demand sites 2–4 times cheaper than electric powerlines, building the hydrogen economy cost-efficiently.

- The pipeline can facilitate emissions savings of up to 20 Mt CO_2e per year by 2050 by enabling industries to embed renewable hydrogen into their processes, and by replacing fossil fuels with e- fuels. This represents around 20 % of current yearly emissions in Finland and Sweden.

- With a hydrogen price of 1.5 €/kg, 65 TWh/a (45 €/MWh) corresponds to a 3 billion Euro hydrogen market, which can be converted to value-added products, such as e-fuels, sponge iron and chemicals, with much higher market values

- The regional hydrogen economy is expected to create up to 25,000 jobs by 2030, and up to 46,000 by 2040.

Enabling reliable hydrogen supply and green industrialisation

Low-carbon hydrogen will be a critical enabler of the transition for hard-to-decarbonise sectors of the economy like steel and metals production. 40 TWh of low-carbon hydrogen demand is expected annually by 2050 for existing businesses in Bothnian Bay to reach climate neutrality, with new steel value chains being an important demand driver.

Nordic Hydrogen Route will facilitate the development of an open access hydrogen market across the region, encouraging businesses to build new operations, such as recent initiatives in the fertilizer and steel industries. E-fuels is another major new industry that will drive the hydrogen demand in Bothnian Bay, with an expected production of around 13 TWh per year by 2050. Overall, annual hydrogen demand for new operations in the region is expected to reach 25 TWh by 2050. Renewable energy potential in the region could support significant additional hydrogen production for new industrial and export opportunities.

Towards Climate Neutrality: Nordic Hydrogen Route could enable emissions savings of up to 20 Mt CO_2e/year by 2050

Emissions savings enabled by the Nordic Hydrogen Route in regional industry represent around 20 % of the combined emissions of Finland and Sweden in 2020. The pipeline has therefore great potential in helping the countries reach their respective climate neutrality targets of 2035 and 2045. The estimate is based on public information about ongoing and proposed regional industrial hydrogen projects, and fossil fuel replacement by e-fuels.

B LOW CALORIFIC GAS AND CONVERSION PROJECTS

Low calorific gas (L-gas) supply in Germany and the Netherlands is in decline. Due to its different gas composition, L-gas markets will have to be converted and integrated into the existing high calorific gas (H-gas) networks. This conversion process has started in all three L-gas importing countries (Germany, Belgium and France).

As a consequence of the difference in gas composition, the L-gas markets in Germany, Belgium and France are physically separated from the H-gas markets in Europe. In addition, some appliances suitable for operating on L-gas are not suitable for H-gas and vice versa. The L-gas market today serves still around 13 million customers[32] and has a considerable share in the gas markets of the Netherlands, Germany, Belgium and France.

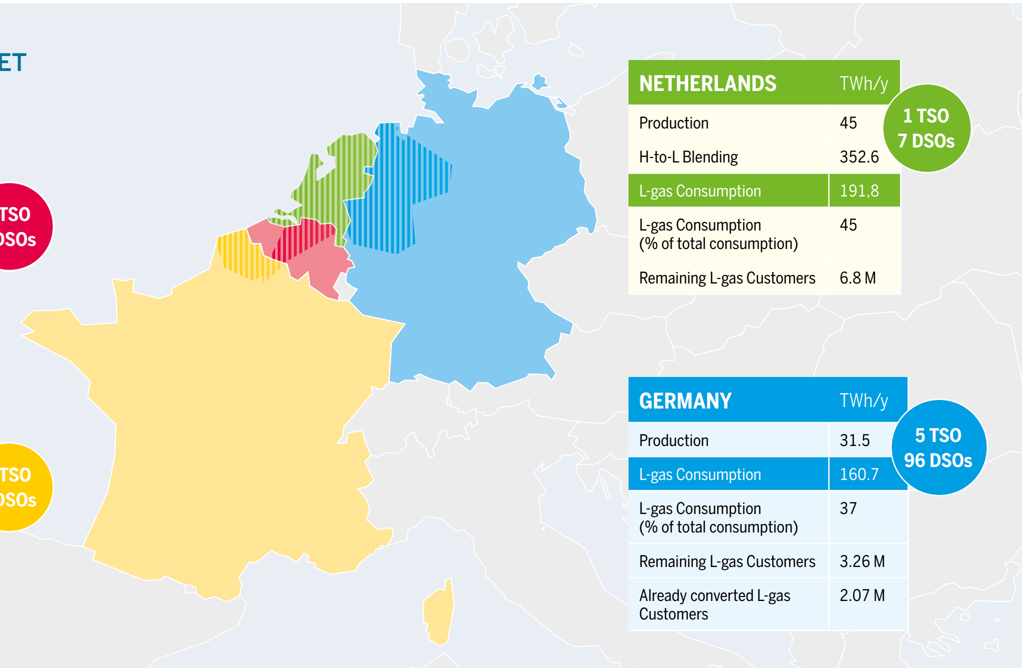
Given the importance of this conversion, a European Coordination on L-gas has been set up within the Gas Platform, with regular meetings between the Member States concerned (Netherlands, Germany, Belgium, Luxembourg and France). In 2019, this Coordination was bolstered by a dedicated "Task Force". Under the aegis of the Dutch Ministry of Economic Affairs and Climate Policies, ENTSOG and the IEA, the Task Force will publish a half-yearly report on the progress of the conversion of the L-gas markets in these countries. More details can be found in the section Supply adequacy outlook.

A collaboration agreement for the conversion of L-gas to H-gas in Belgium and France was also concluded between Gasunie Transport Services, Fluxys and GRTgaz. Regular technical exchanges between Belgian, German and French operators are also being held to discuss the conversion processes in each country.

In the next sections, the status of the L- to H-gas conversion will be described for each country in further details. Lastly, an outlook regarding L-gas demand and supply evolution until 2030 is given.

EUROPEAN L-GAS MARKET

Rounded figures



BELGIUM	TWh/y
L-gas Consumption	37.7
L-gas Consumption (% of total consumption)	9
Remaining L-gas Customers	0.83 M
Already converted L-gas Customers	0.75 M

1 TSO 4 DSOs

FRANCE	TWh/y
L-gas Consumption	38.8
L-gas Consumption (% of total consumption)	9
Remaining L-gas Customers	1.2 M
Already converted L-gas Customers	0.2 M

1 TSO 3 DSOs

NETHERLANDS	TWh/y
Production	45
H-to-L Blending	352.6
L-gas Consumption	191,8
L-gas Consumption (% of total consumption)	45
Remaining L-gas Customers	6.8 M

1 TSO 7 DSOs

GERMANY	TWh/y
Production	31.5
L-gas Consumption	160.7
L-gas Consumption (% of total consumption)	37
Remaining L-gas Customers	3.26 M
Already converted L-gas Customers	2.07 M

5 TSO 96 DSOs

Figure 31: European L-gas market in 2022 (Source: L-gas Market conversion review, NW GRIP TSOs)[33, 34]

32 For Germany, the number of appliances is taken into account and not the number of customers.
33 In Germany, the L-gas market is measured in number of appliances rather than number of customers.
34 L-gas consumptions are relevant for GY 2021–2022 and are partly estimates.

1 L-GAS SUPPLY FROM THE NETHERLANDS

About 90 % of L-gas demand in NW Europe is supplied from the Netherlands, via the Groningen gas field or by blending a mix of various H-gas sources with nitrogen to make pseudo L-gas. These H-gas sources can be domestic production from small fields or from imports. Historically, the main supplier of L-gas in NW Europe was the Groningen gas field in the Netherlands. This can be seen in the graph below which shows the historical gas production from the Groningen gas field.

After the earthquake in January 2018 near Zeerijp, the Minister of Economic Affairs and Climate Policy decided to end gas extraction from the Groningen field as soon as possible while preserving the security of supply and the 'gas-quality-neutral' gas market (TTF without Wobbe labels). To achieve this, a large number of measures have been initiated on the instructions of the Minister.

Several of these measures have already been implemented:

- increased use of the baseload nitrogen installations, from 85 % to 100 %;
- procurement of an additional 80,000 m^3/h of nitrogen for the Wieringermeer blending station;
- export of pseudo L-gas via the Oude Statenzijl export station;
- blending station built by GTG-Nord in Germany, from where about one third of the German L-gas market in the GTG-Nord area is supplied with H-gas;
- filling the gas storage Norg with pseudo L-gas.

In addition, a number of measures are currently being implemented in the Netherlands and in other countries, specifically:

- converting nine industrial large-scale consumers from L-gas to H-gas. Four industries have stopped their intake of G-gas at 1 October 2022, the remaining five industries will be converted in the years after.
- expanding nitrogen capacity through the construction of the Zuidbroek nitrogen installation[35];
- repurposing the LNG peak shaver facility as a blending station;
- converting the domestic L-gas market to H-gas in Belgium, France and Germany (details in the following subsections);
- converting Grijpskerk gas storage facility from H-gas to L-gas to prepare the gas facility to take over the backup role of the Groningenfield and enabling the early closure of the field.

Based on the measures already implemented and those in progress, calculations by GTS show that the Groningen field can be closed permanently sometime between October 2023 and October 2024[36]. In light of the current geopolitical situation however, GTS advises not to take irreversible decisions about the closing of production locations of the Groningen field. From gas year 2022/2023 and further, the Groningen field will be in standby mode – on the pilot flame so to speak. During that time, production from the Groningen field for security of supply will only be needed for times of extreme cold and in the event of a failure of a L-gas means. There are a number of exceptional circumstances in which additional production from the Groningen field is allowed, namely a major interruption from the supply of the nitrogen installations, an unexpected quality or shortage of the H-gas, a disruption in the gas distribution network and in case of extreme low temperatures (−9 degrees Celsius or colder).

Pseudo L-gas is playing an increasingly important role in reducing Groningen gas production and closing the field permanently. In Gas Year 2018/2019, 65 % of the NW Region L-gas demand was fulfilled with pseudo-L-gas, this is expected to increase to over 93 % of L-gas produced in the Netherlands in GY 2022/23. Moreover, in the GY 2023/24, pseudo L-gas is expected to account to 100 % of L-gas produced in the Netherlands and is set to provide the entire upward production flexibility necessary to meet demand in a cold GY.

Pseudo L-gas is exported to neighboring markets in Belgium, France and Germany, where it serves dedicated L-gas consumers –who will be converted to other sources of energy, most notably H-gas, as a result of the Groningen phase-out.

35 Information about the commissioning date will be communicated via https://www.gasunietransportservices.nl/en/transparency/remit/urgent-market-messages
36 Advies leveringszekerheid voor benodigde Groningenvolumes en -capaciteiten voor gasjaar 2022/2023 en verder, d.d. 31 januari 2022, ons kenmerk L 22.0055.

The gas infrastructure operators of Belgium, France and Germany have made arrangements to undertake extensive conversion programs, mainly switching L-gas consumers to H-gas, to reduce the L-gas supply from the Netherlands: by GY 2029/30, exports of Dutch L-gas will be reduced to nearly zero.

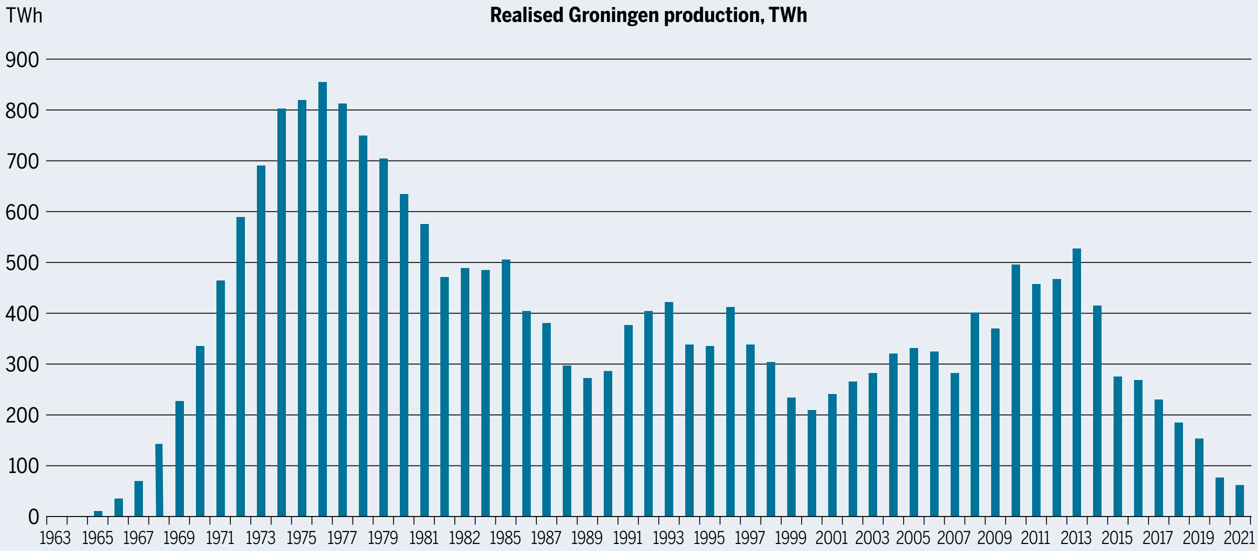


Figure 32: Realised Groningen production (TWh) (Source: NAM)

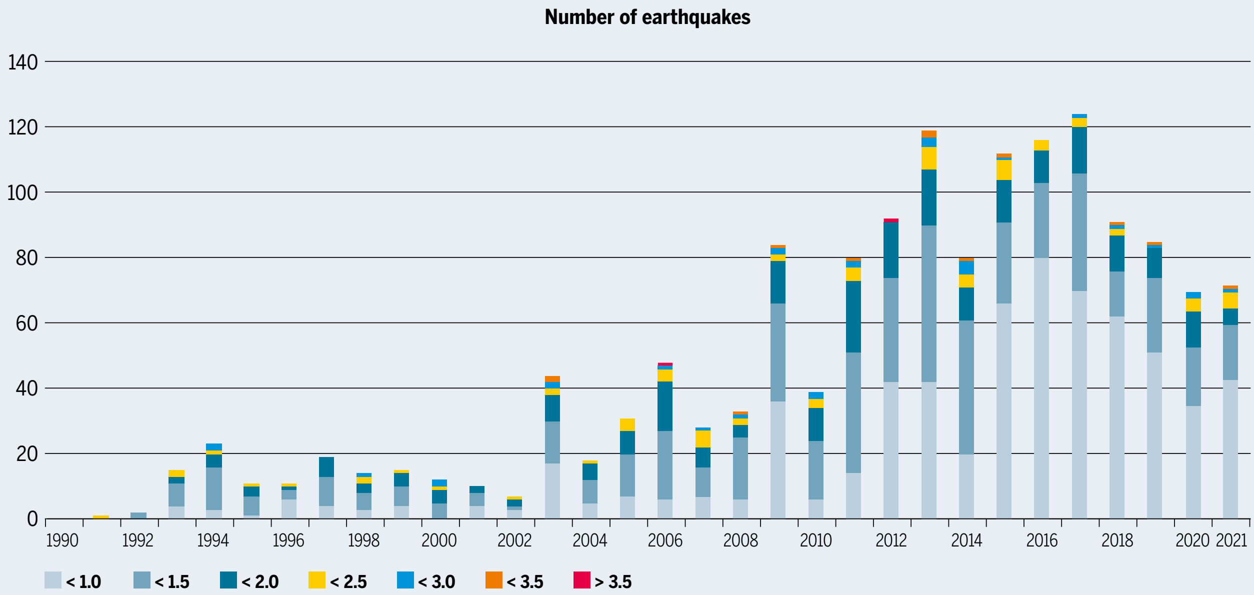


Figure 33: Earthquake evolution (Source: KNMI)

2 L-GAS MARKET IN GERMANY

The L-gas market historically developed in the north-western part of Germany, close to indigenous production and the Dutch border. By the end of 2022, it consists of approximately 3.26 million appliances, supplied via the networks of 5 TSOs and 96 DSOs. Several underground storage facilities are also connected to the TSOs' networks.

Figure 34: L-gas transmission network Germany (Source: TSOs Germany)

Similar to the situation in the Netherlands, the German indigenous production is also declining. Figure 35 shows an indication of the yearly production volumes for L-gas for the gas years 2022/23 to 2029/30.

To meet the challenges of declining supply, the German TSOs, in close cooperation with market participants and national authorities, have started a process for market conversion from L-gas to H-gas, which will last till 2029. The conversion process, integrated in the interim status of the Gas Network Development Plan 2022–2032[37], is based on 46 local grid areas.

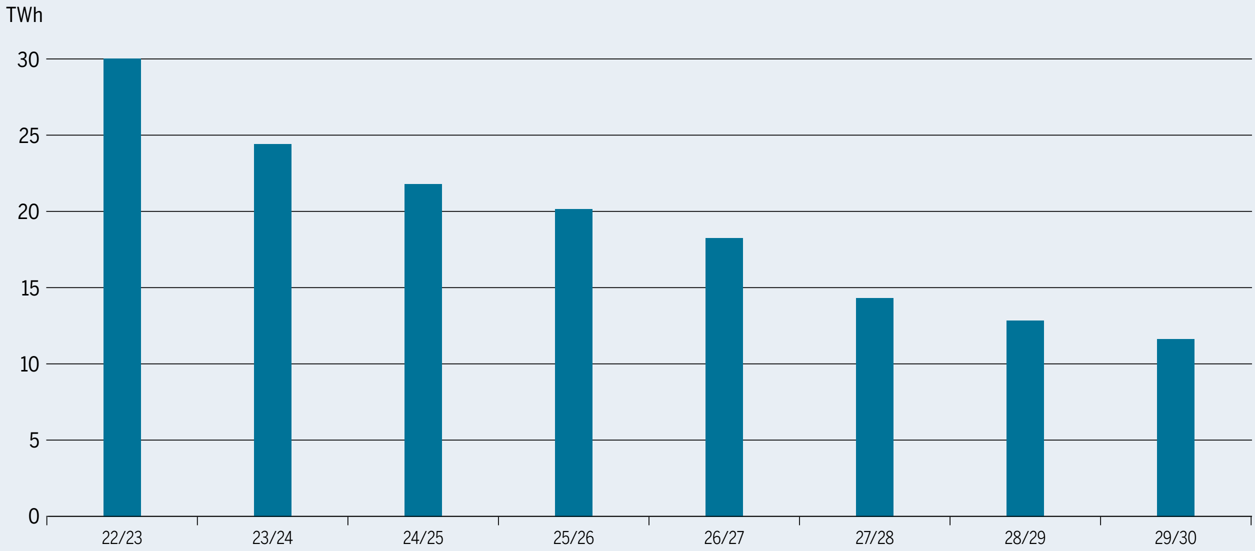


Figure 35: Indication of the L-gas production in Germany (GY 2021/22–2029/30) in TWh
(Source: L-Gas Market Conversion Review – Summer Report 2022, Task Force Monitoring L-Gas Market Conversion)

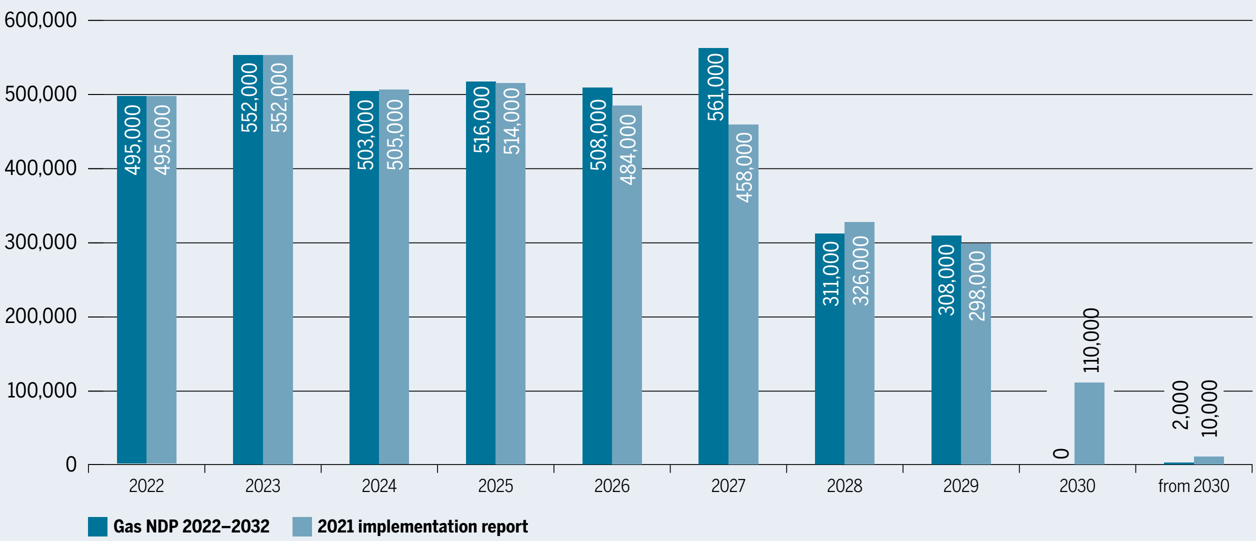


Figure 36: Number of consumer appliances to be modified per year (Source: FNBGas)

37 https://fnb-gas.de/wp-content/uploads/2022/07/2022_07_06_NEP-Gas-2022-2032-Zwischenstand.pdf

The conversion of customers started in 2015 with smaller areas. During the years 2015–2018, several early conversions have been implemented ahead of the scheduled dates for conversion, which served to bring down Groningen production earlier. By the end of 2022 approximately 2.07 million installed appliances (approximately 40 % of all German L-gas appliances) were successfully converted to the supply of H-gas. The respective grid areas were switched to H-gas without problems. In the market conversion all appliances of customers supplied with L-gas will have to be checked and adapted to H-gas. The number of customers that can be converted per year is limited by the number of available experts who can handle the adaption. The conversion of the German L-gas market is therefore planned over a long period (starting in 2015 till 2029) due to the large number of L-gas customers. The number of customers/appliances converted per year was constantly increasing from year 2015 to 2021. In 2022, 495,000 installations were converted, leading to an estimated volume effect of 21.2 TWh. Between gas years 2022/23 and 2028/29, over 3.26 million of gas appliances will still need to be converted.

For the conversion of some areas in the later stages of the plan extensive technical changes on the system are required. The long planning horizon of the conversion plan allows for technical adaption of the system in time. On the transport system side, adaptation of the infrastructure is needed not only in order to connect the (former) L-gas system to the H-gas grid but also to enhance system capacity for the additional volume that is needed to supply the converted market. The final German national network development plan 2020[38] identifies approximately 80 projects related to the market conversion from L-gas to H-gas. The complexity of these projects ranges from single valves and metering stations to new pipelines and compressor stations. About 300 km of new pipelines and 116 MW of additional power on compressor stations are needed to enhance the transport system for the market conversion.

Overall, the total costs for the conversion from L- to H-gas in Germany are estimated at approximately € 4 billion.

38 https://fnb-gas.de/wp-content/uploads/2021/09/fnb_gas_nep_gas_2020_de-1.pdf

Picture courtesy of Open Grid Europe

3 L-GAS MARKET IN BELGIUM

As abovementioned, the Dutch authorities have announced that exports of L-gas to Belgium, France and Germany will cease by 2030. To guarantee security of supply, Belgium, France and Germany have started converting their national L-gas markets to H-gas. There is H-gas available on the markets and the existing L-gas transmission infrastructure can be re-used for H-gas, resulting in an economically optimal solution for all users.

At the request of the Belgian authorities, Synergrid (Federation of Electricity and Gas System Operators in Belgium) produced an indicative conversion timetable (Figure 37). This indicative timetable is based on repurposing existing Belgian infrastructure as much as possible with a view to avoiding investments that are only necessary for the transition period.

In 2020, after a successful completion of the L/H conversion phases to date, the distribution and the transmission system operators identified opportunities to optimise and shorten the conversion planning. This way, the entire Belgian gas market should be fully converted to H-gas by the end of 2024 instead of 2029, following the new indicative conversion planning from Synergrid (Figure 37). However, the L-gas transit from the Netherlands to France will be maintained for several years in order to supply the French L-gas market.

For the conversion to be a success, Fluxys Belgium must gradually adapt its grid to ensure the continuity of transmission services for both converted and non-converted markets.

The conversion phases scheduled for 2016 to 2022 were completed as planned with more than 750,000 connections already converted over this period, including some industrial users directly connected to the Fluxys Belgium grid.

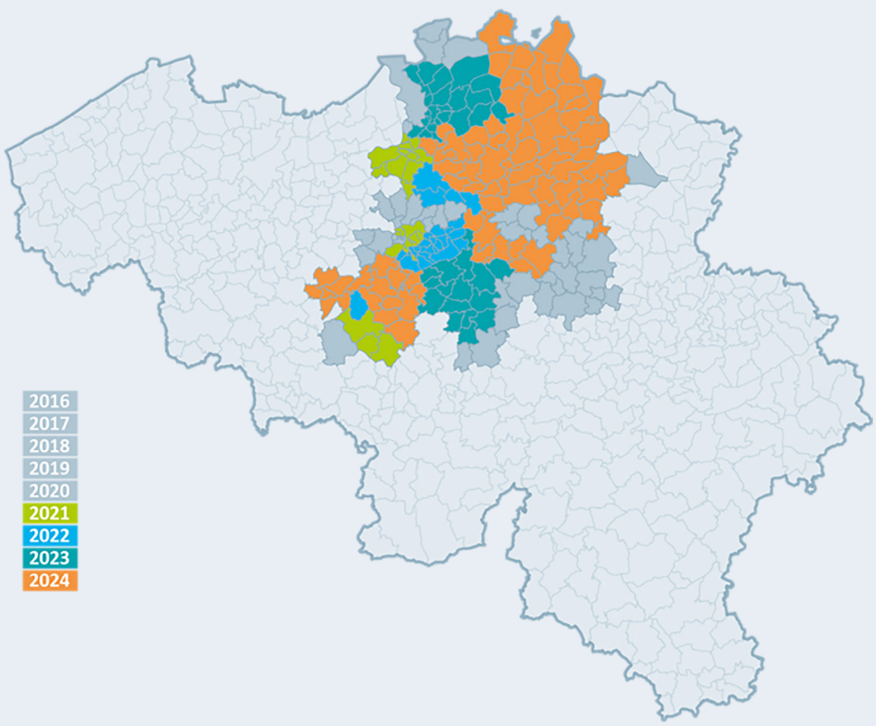


Figure 37: Indicative timetable for the conversion of the L-gas market (Source: Synergrid)

The main changes to be made to the transmission system involve connecting and gradually integrating L-gas transmission infrastructure into the H-gas transmission system. Following the conversion timetable, existing connections between the L- and H-gas grids will be adapted, if necessary, in order to selectively supply H-gas to distribution system operators and industrial customers. The L-gas network to be converted is shown in Figure 38 in grey.

However, on some parts of the grid, the capacity of the existing connections will not be sufficient and some upgrades will have to be made, especially on connections between the major L-gas (north-south) and H-gas transmission routes (east-west).

Maintaining capacity to the L-gas markets that are not yet converted is a significant constraint, especially as regards export capacity to the French market that needs to be guaranteed. Since there is only a single entry point for L-gas at Hilvarenbeek and a single exit point at Blaregnies (for transmission to France), one of the two parallel L-gas pipelines (Dorsales) will need to continue transmitting L-gas until the conversion of the French market is complete. To this end, there is close coordination between Fluxys Belgium and the Dutch and French TSOs (GTS and GRTgaz).

As such, the Belgian market can only be converted by gradually supplying H-gas from the second Dorsale, primarily from an interconnection in construction at Winksele at the crossroad of the major H-gas transmission axis Zeebrugge – Eynatten and the Dorsales, in the heart of the L-gas market awaiting conversion. With that in mind, the conversion process will run from south to north, gradually pushing back the L-gas to the entry point at Hilvarenbeek.

At each stage of the conversion process, the affected L-gas customers need to be supplied with H-gas. Since the Hilvarenbeek entry point is only supplied with L-gas at present, the companies shipping gas to these new customers need to have entry capacity at another (H-gas) entry point on the Fluxys Belgium grid.

Following their conversion to H-gas, the main west-east and north-south transmission pipelines on the Fluxys Belgium grid will be able to play a major role in replacing L-gas on the German and French markets, in terms of both diversity and security of supply and access to LNG sources.

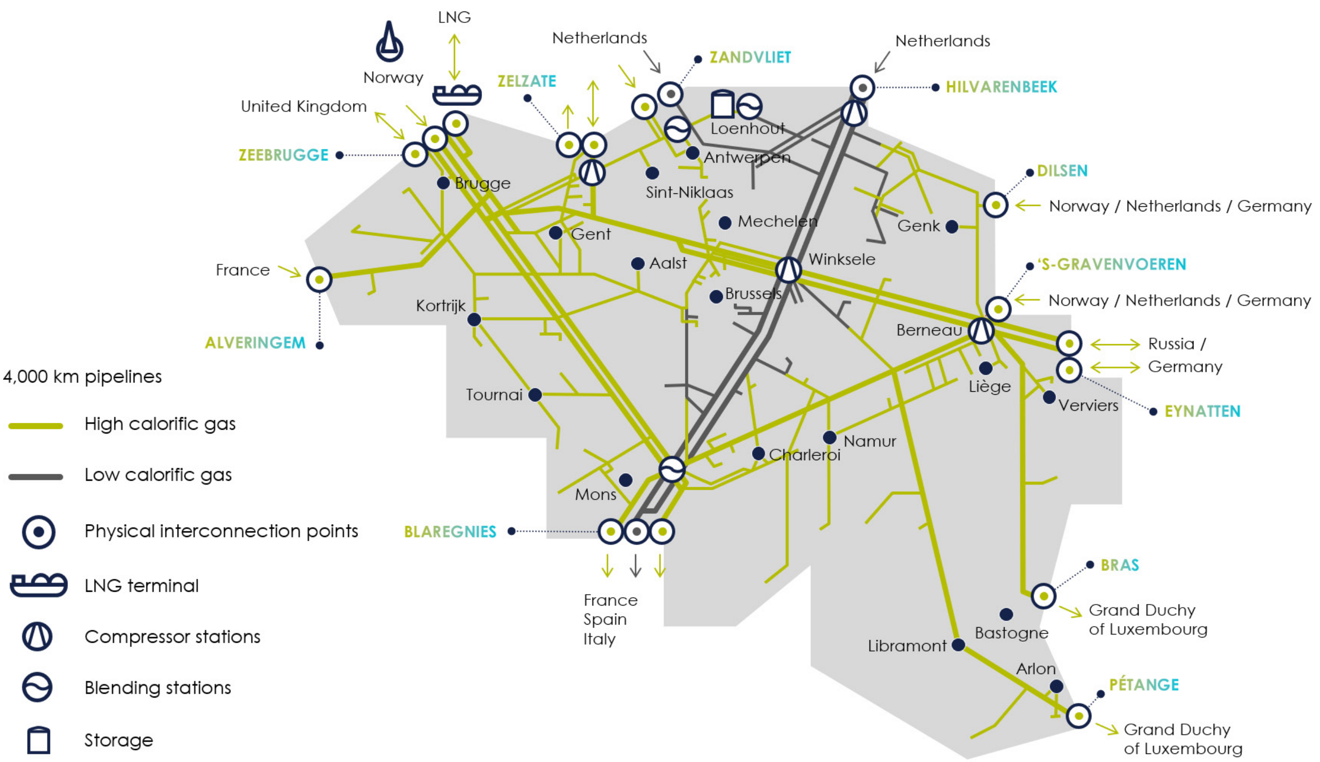


Figure 38: Gas network Fluxys Belgium (Source: Fluxys Belgium)

4 L-GAS MARKET IN FRANCE

The low calorific value gas network supplies natural gas to most of the Hauts-de-France region. L-gas accounts for around 10 % of total French consumption and 1.3 million customers, including around 100 industrial consumers that are directly connected to the transmission network.

The L-gas consumers are supplied by one entry point from Groningen through Belgium at Blaregnies/Taisnières L. The L-gas network also includes a peak-conversion facility from H-gas to L-gas at Loon Plage, and an underground storage (UGS) facility at Gournay.

Considering the end of the Dutch L-gas exports by 2030 and the decisions to cease the Groningen production, the continuity of transmission to consumers must be ensured by converting the L-gas network into H-gas, which already supplies most of French consumers. In addition to the modifications of the network, an intervention at each consumer will be necessary to take an inventory of appliances using natural gas, and potentially apply new settings, or even replace them.

Setting up a legal and regulatory framework was a prerequisite for the setting up of the conversion plan, in order to define the operating schedule, the responsibilities of the different stakeholders and the technical requirements. A decree, issued March 23, 2016 (n°2016–348) specifies the regulatory framework and the general organisation of the conversion operation. It introduces a pilot phase between 2016 and 2020, a coordination committee led by national authorities, and a draft joint conversion plan by the network and storage operators, submitted by operators to the relevant ministerial authorities on 23 September 2016 and updated in November 2020[39].

This conversion plan is based on a breakdown of the current L-gas consumption into 20 geographical sectors. Each sector will be converted independently and successively, from Dunkerque to Taisnières, enabling a gradual conversion until 2028 at the latest, with a conversion rate compatible with the interventions required for each of the 1.3 million customers.

Figure 39: L-gas conversion by consumption sectors (Source: GRTgaz)

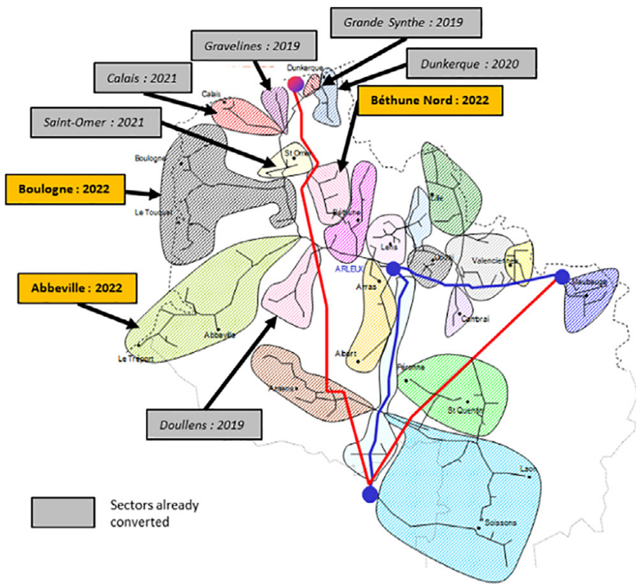


Figure 40: Mapping of the conversion sectors according to the L-gas conversion plan (2019) (Source: GRTgaz)

39 https://www.grtgaz.com/sites/default/files/2022-03/20201125-Plan-de-conversion-revision-2020.pdf

Implementing the planned conversion process for customers connected to the distribution network requires the use of a gas known as "L+". This gas complies with L-gas specifications, but with a Wobbe index stabilised within a tighter range at the top of the L-gas range. L+ gas makes it possible to adjust the H-gas configuration of customers' devices, when necessary, prior to the arrival of H-gas.

Since 1 April 2016, L+ gas specifications have been incorporated into the Dutch regulations for gas transported to Belgium and France. The technical requirements of GRDF, Storengy and GRTgaz have also been modified to take these L+ gas requirements into account.

On the distribution network, the conversion process begins with the supply of L+ gas, then an inventory of all appliances is done in each area to be converted, followed by interventions on the appliances according technical requirements, and finally quality checks on those tasks.

The conversion process began with a pilot phase in order to test the conversion procedure.

During the gas year 2018/19 the conversion of the L-gas network was carried out first in the Doullens area, mostly rural with a majority of individual housing and then in the Gravelines area, a urban area with collective housing. The Grande Synthe area and the Dunkerque area (2020) followed. The pilot phase successfully converted 77,000 customers.

After the successful achievement of the pilot phase, the deployment phase began in 2021.

Over 1.26 million of gas consumers will need to be converted between GY 2021/22 and GY 2029/30, translating into a total volume of 38.5 TWh/y. Consequently, L-gas imports from the Netherlands to France are expected to fall to 0 by GY 2029/30, both in an average and cold GY.

By the end of 2022, 10 % of the conversion will have been completed.

In order to ensure the continuity of supply for both L-gas and H-gas consumers and enabling the progressive conversion by areas, adaptations of the transmission system were required.

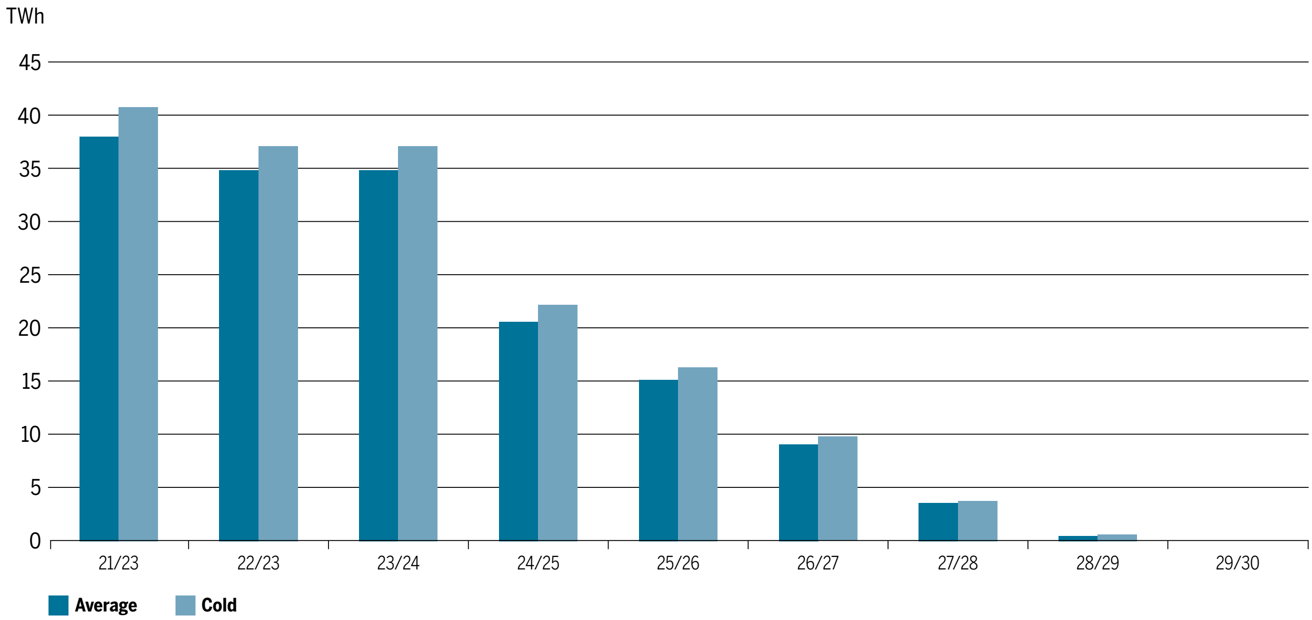


Figure 41: France's consumer demand for L-gas from the Netherlands (GY 2021/2022 to GY 2029/2030) for average and cold GYs (Source: L-gas Market conversion review, winter report 2022)

GRTgaz's investments have been designed and decided in three parts:

- pilot phase for construction and modification work needed for the planned conversion for the period 2018–2020, decided in 2016 for a cost of approximately € 47 million;
- deployment phase 1 for construction and modification work needed for the planned conversions for the period 2021–2024, decided in 2019 for a cost of approximately € 30 million, currently in progress;
- deployment phase 2 for construction and modification work needed for the planned conversions for the period 2025–2028, currently in study phase to be decided in 2023.

The works required for each parts consists of:

- shutting down the H-gas to L-gas adapter in Loon Plage
- modifying substations and the compressor station of Taisnières to new flow patterns
- connecting the H-gas network to the L-gas network,
- isolating the L-gas and H-gas networks,
- adapting the instrumentation used to monitor and control the quality of the gas transported,

Under the incentive regulation, these projects were audited by the CRE in order to set a target budget.

The conversion of the Gournay storage facility will occur in 2026. Until then, the quantity of L-gas injected into the storage will be gradually reduced, while ensuring a minimum level of annual cycling.

Overall, the total costs for the conversion from L-gas to H-gas in France are estimated at approximately 1 billion euros.

The L-gas conversion project has finally some consequences on the Transmission offer, including:

- the disappearance of the "peak" H-gas to L-gas conversion service in spring 2021 following the H-gas conversion of the network to which the Loon-Plage H-gas/L-gas adapter is connected;
- a reduction in the firm entry capacity at Taisnières B from 230 GWh/day to 108 GWh/day in 2025

These changes correspond to GRTgaz's current vision based on the draft conversion plan submitted to the authorities. However, the above deadlines may change if the planned conversion schedule is altered.

To date, GRTgaz has not identified any need for additional capacity for the Virtualys virtual interconnection point by 2025 and beyond. If necessary, all or part of the equipment can hence be reused for the L-gas capacity.

An increase in H-gas capacity would require investments, whose triggering would depend on market demand. Otherwise, the entry capacity at Taisnières B will not be converted into H-gas.

Picture courtesy of GRTgaz

5 SUPPLY ADEQUACY OUTLOOK

This section compares the outlook of L-gas demand and supply evolution until 2030 when conversion processes are supposed to be finalised in Belgium, France and Germany.

An important part of L-gas monitoring reports published by the Task Force Monitoring L-Gas Market Conversion is the supply-demand balance for the four L-gas consuming countries for the coming years. The supply-demand balance of the latest L-gas Monitoring report is shown in Figure 42 & Figure 43. The red line indicates falling demand in the entire L-gas region for the next eight gas years. The bars indicate the different sources of supply in the Netherlands.

Overall, the Task Force Monitoring L-Gas Market Conversion Summer report 2022 showed that demand within the entire L-gas region can be covered by production from the Groningen field, production in Germany, enrichment of L-gas and H-gas blended with nitrogen.

It must be noted, that the Covid-19 induced lockdowns had only a minor impact on the overall schedule of the conversion programs in 2020 and no impact since 2021.

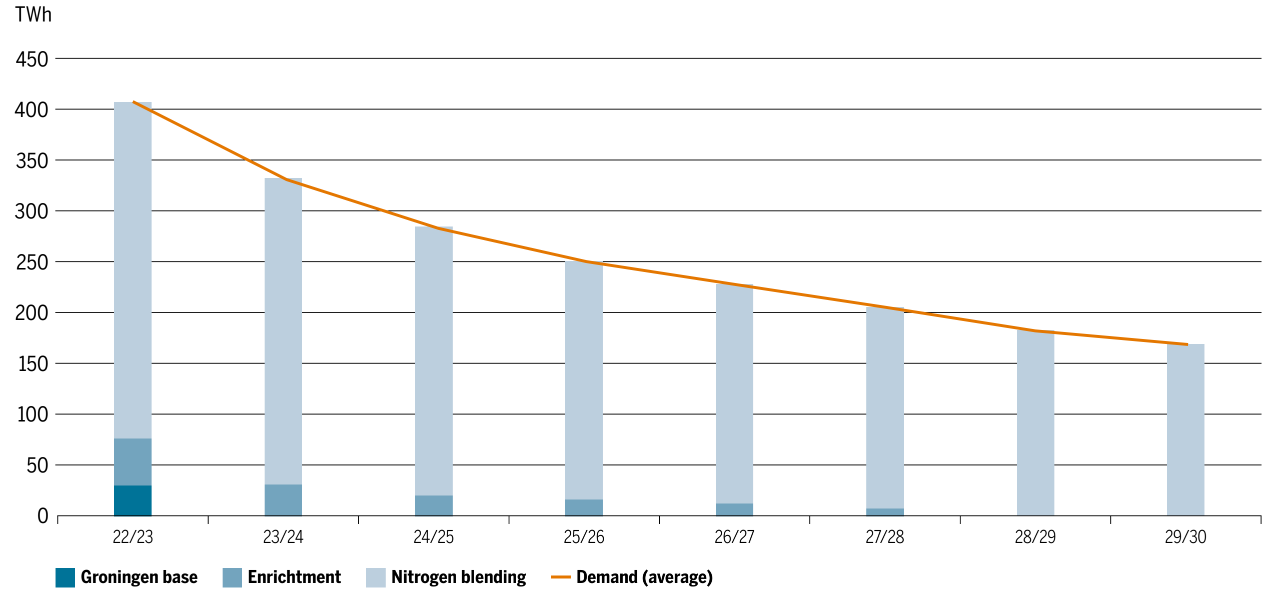


Figure 42: L-gas supply-demand balance in an average year (GY 2022/2023–GY 2029/30) (Source: Task Force Monitoring report)

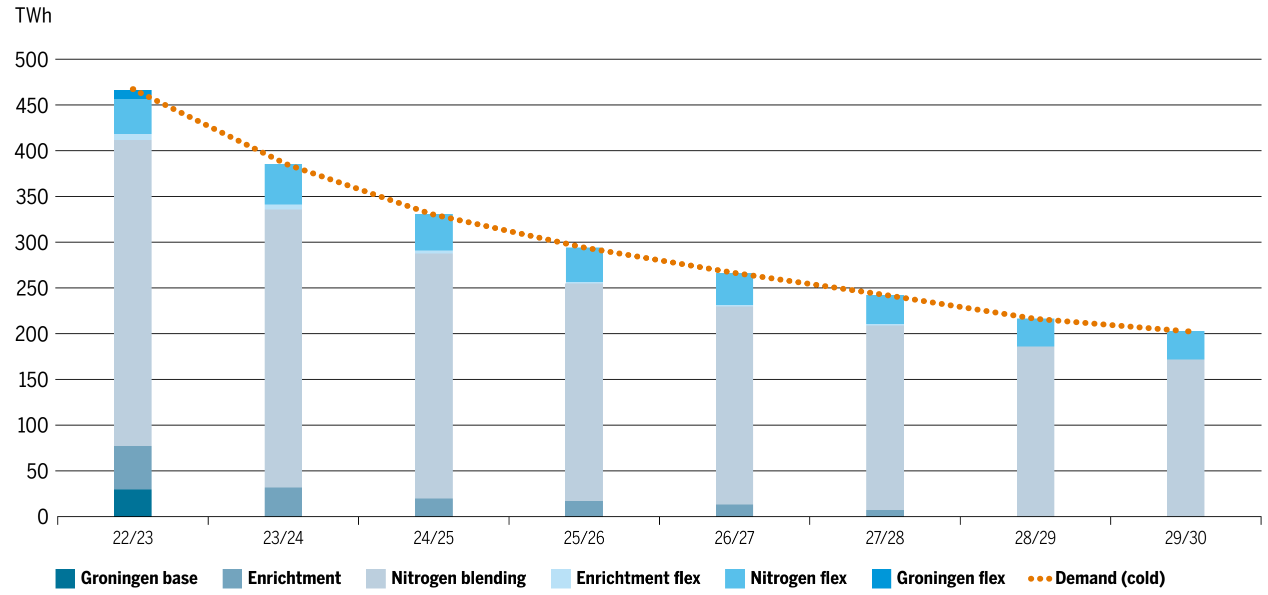


Figure 43: L-gas supply-demand balance in a cold year (GY 2022/2023–GY 2029/30) (Source: Task Force Monitoring report)

CONCLUSIONS

This report represents the fifth edition of the NW GRIP as prepared by the TSOs of the NW Region.

The first part of the report provides an overview of projects and initiatives that gas TSOs are involved in to facilitate the security of supply and the decarbonisation of the gas infrastructure across Northwest Europe. These initiatives demonstrate the commitment of TSOs from the NW Region to actively engage in the security of supply and the decarbonisation of the gas and energy system as a whole. The technologies adopted vary from Member State to Member State, reflecting the differing focuses of national policies.

The second part of the report describes the developments in the L-gas region. It can be concluded that the measures to increase conversion capacity and reduce L-gas demand in the Netherlands and the planned L to H infrastructure conversion in France, Belgium and Germany are on track. Furthermore, it is important to maintain good international cooperation and alignment between the concerned countries in order to ensure security of supply in the L-gas region for the coming years.

The NW GRIP TSOs hope that this report offers a valuable insight into the main dynamics of the NW Region and welcome any stakeholder feedback for further improvements in the future.

LIST OF FIGURES

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