ENERGINET gasunie

HYDROGEN MARKET ASSESSMENT REPORT

FOR DENMARK AND GERMANY

INTRODUCTION

The significant European focus on green hydrogen as an important energy carrier in the green energy transition is the basis for an intensified cooperation between the German and Danish transmission system operators, Gasunie and Energinet[1], on planning and realization of a crossborder hydrogen infrastructure. The cooperation started in 2020 resulting in a publication of a joint Pre-Feasibility Study for a Danish-German Hydrogen Network (April 2021), assessing the potentials of a hydrogen interconnection between the countries.

In August 2022 Gasunie and Energinet have strengthened the basis for their cooperation by signing a Memorandum of Understanding (MoU). This includes elaboration on the initial technical design, coordination of the project realization plans and necessary milestones on both sides of the border, aligned development of the market models and operational frameworks as well as further aspects.

Market signals, requesting a crossborder hydrogen infrastructure by end of this decade become stronger. Also, the political focus on green hydrogen and the need for a crossborder infrastructure have been intensified in both countries. The recent political joint Declaration of Intent focuses on a cooperation between the countries and the rollout of a hydrogen infrastructure from the year 2028.

The aim of this report is to provide information about the current expectations for the hydrogen market development in both countries and assess next steps, needed for a realization of a crossborder hydrogen infrastructure. Both companies see necessity and added value in the continuous and transparent dialogue with all relevant stakeholders to enhance the assessment of the infrastructure value and reduce financial risks of hydrogen related investments.

[1]On behalf of the future hydrogen operator(s) in Denmark awaiting a political agreement.

POLITICAL AGREEMENT – JOINT DECLARATION OF INTENT

The Danish minister of climate, energy and utilities and the German minister of economy and climate protection concluded on the 24th of March 2023 a Joint Declaration of Intent on the Cooperation on Green Hydrogen and the Realization of a Landbased Border Crossing Hydrogen Pipeline Between Northern Germany and Western Denmark.

The objective of this Joint Declaration of Intent is to reconfirm and reinforce the participants' bilateral cooperation on green hydrogen. The participants will cooperate on advancing the rollout of transmission infrastructure for green hydrogen between Western Denmark and Northern Germany from the year of 2028 enabling a large scale transmission interconnector for green hydrogen between Denmark and the Federal Republic of Germany.

Read more here.

FIRST PTX TENDER IN DENMARK

In April 2023 Denmark launched a first PtX Tender. The tender is being held to facilitate production of green hydrogen by using renewable energy sources and is a part of Denmark's goal to reach between 4 and 6 GW of electrolysis capacity by 2030. The winning bidder(s) must have the project(s) built to full capacity and start green hydrogen production within four years of signing the contract with the Danish Energy Agency. The state support of the green hydrogen production tender amounts to DKK 1.25 billion (approximately EUR 168 million).

Read more here (in Danish).

May 2023

KEY MESSAGES

Political ambitions, related to the energy transition, as well as signals from hydrogen market players, intending to produce green hydrogen in Denmark and to consume hydrogen in Germany are reflected in scenarios used for the European Ten-Year Network Development Plan (TYNDP) as well as scenarios used for the national development plans. All of these scenarios predict a considerable rampup of the hydrogen market in both countries.

Based on the assessment of the hydrogen market development our key messages are:

- The development of large scale production of green hydrogen in Denmark and the demand for green hydrogen evolving in Germany are compatible. Thus, a crossborder hydrogen infrastructure becomes indispensable to enable the envisaged exchange between the countries.
- Denmark expects to be a net exporter of green hydrogen. A large part of the hydrogen, produced in Denmark is expected to be exported. The hydrogen export is assumed to increase from 15 TWh in 2030 to 79 TWh in 2050 based on the national scenarios or even up to 98 TWh, considering the European scenarios. The short-term potentials may also develop faster as indicated via market signals.
- Germany expects to become a net importer of green hydrogen. The estimated low carbon hydrogen demand increases from 93 TWh in 2030 to more than 500 TWh in 2050. One third of the German demand is estimated to be covered by the domestic production. The remaining volumes need to be imported, which to a significant extent can be released through onshore pipeline connections.
- Gasunie and Energinet jointly work on planning and realization of a cross border pipeline connection by end of 2028 supporting the transportation needs. This is coordinated with national hydrogen infrastructure planning in both Denmark and Germany to reach both Danish hydrogen production centers and German hydrogen demand centers. However, both Gasunie and Energinet acknowledges that the timely realization of a cross border pipeline connection is challenging and requires quick political solutions on open questions especially the financing and the acceleration of public permits.
- The ambitious timeline requires support from all stakeholders, such as potential network users (producers, off-takers and traders of hydrogen) as well as local and national authorities and communities. Commitments from network users are required, to be able to make timely investment decisions. A process for binding commitments for the utilization of the transport infrastructure from Denmark to Germany is planned to be launched before the end of 2023.

PROJECT OF COMMON INTEREST ACC. TO TEN-E REGULATION

In December 2022, Energinet and Gasunie submitted applications for their respective parts of the infrastructure to the European Commission for a PCI (Projects of Common Interest) status of the crossborder hydrogen transport infrastructure.

Projects with a PCI status benefit from accelerated permitting procedures, potential regulatory exemptions, and European funding possibilities. The PCI-status decision is expected in Q4 2023.

PRE-FEASIBILITY STUDY FOR A DANISH-GERMAN HYDROGEN NETWORK FROM 2021

In April 2021 Gasunie and Energinet published a pre-feasibility study in which it was concluded that a significant part of future German demand on green hydrogen could be covered by domestic production and imports from Denmark. A connection between the two countries can be established stepwise, partially based on the repurposing of existing natural gas infrastructure and in a costefficient manner.

Read more here.

ENABLING OF INTEGRATED DANISH-GERMAN HYDROGEN MARKET

EXPECTATIONS ON MARKET DEVELOPMENTS

GERMANY
For the market development expectations analysis, the TYNDP Distributed Energy Scenario (TYNDP DE) was taken as a basis due to its focus on system integration. The TYNDP DE energy system data was further refined to a subsectoral and regional level. The disaggregated energy system data was made available by use of the Energy Transition Model (ETM), an interactive tool for energy modelling developed by Quintel. Statistical data was then used to develop regional disaggregation keys for all (sub)sectors. Furthermore, on the supply side, own assumptions were developed on the regional distribution of national hydrogen production capacities and the development of the contributions of pipeline and shipbased imports to the total supply over time.

The estimated low carbon hydrogen demand in the selected base scenario increases from 93 TWh in 2030 to more than 500 TWh in 2050 (Figure 1). The scenario reflects a comprehensive use of hydrogen across all sectors. Industrial demand proofs to be the strongest driver of hydrogen demand from 2030 onwards, followed by the transport sector in the mid- to longterm. Within the industry sector, hydrogen is predominantly used as feedstock in the chemical industry and reduction agent in the steel industry. Hydrogen use in shipping and aviation as well as for heavyduty transport dominate the transport sector which requires close to 150 TWh LHV (lower heating value) in 2050. Both building and power sector show less demand in terms of energy but have a significant contribution to peak hydrogen load, especially on cold winter days with limited electricity generation from wind and solar PV plants.

Of the approximately 90 TWh demand in 2030, only one third is expected to be produced domestically (Figure 2). The remaining 60 TWh will be imported, which can be released via a mix of import terminals (such as converted LNG terminals or ammonia terminals with subsequent cracking facilities), offshore or onshore pipeline connections (e.g., to the Netherlands, Denmark and Norway).

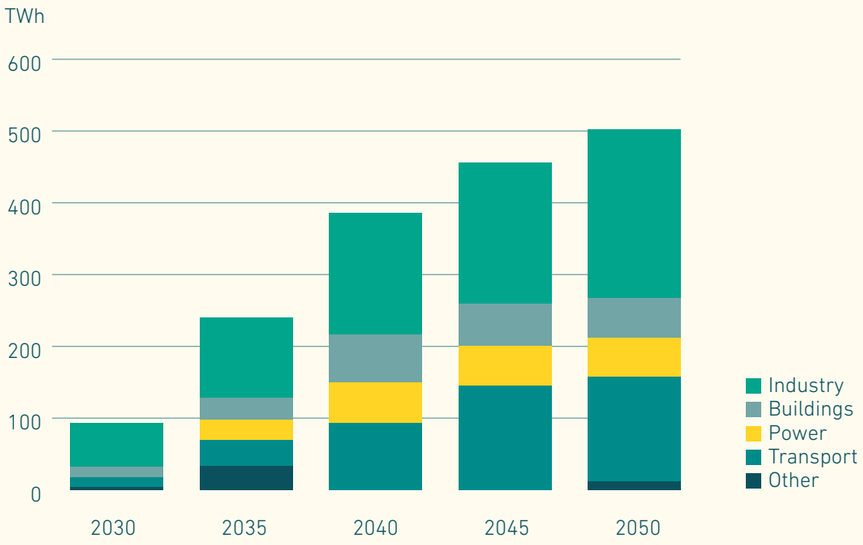

Figure 1 Low-carbon hydrogen demand development per sector in TWh (LHV)

TYNDP
Every two years, the European Electricity and Gas TSOs publish a Ten-Year Network Development Plan (TYNDP). The plan gives an overview of the European transmission system projects till 2040 and is the basis for the European Commission to evaluate Projects of Common Interests.

TYNDP-SCENARIOS
The latest version of the European scenarios was jointly published by ENTSO-G and ENTSO-E in the TYNDP 2022 Scenario Report in April 2022. Three alternative developments are described:

1) National trends (NT). Aggregation of national policies and strategies as stated end of 2020

2) Distributed Energy (DE). Higher European autonomy with renewable and decentralised focus

3) Global Ambitions (GA). Global economy with centralised low carbon and RES options and net zero in 2050 on EU level

The Distributed Energy Scenario is applied here because it is driven by a willingness of society to achieve energy autonomy based on widely available renewable energy sources. The scenario is characterized by a decentralized approach to decarbonization and reaches 55 % GHG reduction in 2030.

The quadrupling of hydrogen demand between 2030 and 2040 is assumed to be mainly satisfied via increasing terminal import volumes and crossborder onshore pipelines. The terminalbased import is expected to peak between 2035 and 2040. Subsequently, lowercost pipeline imports are gaining importance and become the most important supply option 2040, contributing to decline in terminal imports in further course. Also, in 2050 a third of German demand will be covered by national production (onshore or offshore).

Germany will be highly dependent on imports of low carbon and renewable hydrogen from the very beginning. The supply is expected to be determined by import points in the north-west of Germany. In general, it can be assumed that regionally defined centers of demand will emerge, whereby the locations of the (petro) chemical and steel industries as well as airports, ports and logistics centers will be of particular importance. Strong regional differences in supply and demand will lead to a rapidly increasing demand for hydrogen transport infrastructure within the country, enabling the transport of hydrogen from the import points (such as Danish Border) to the demand centers.

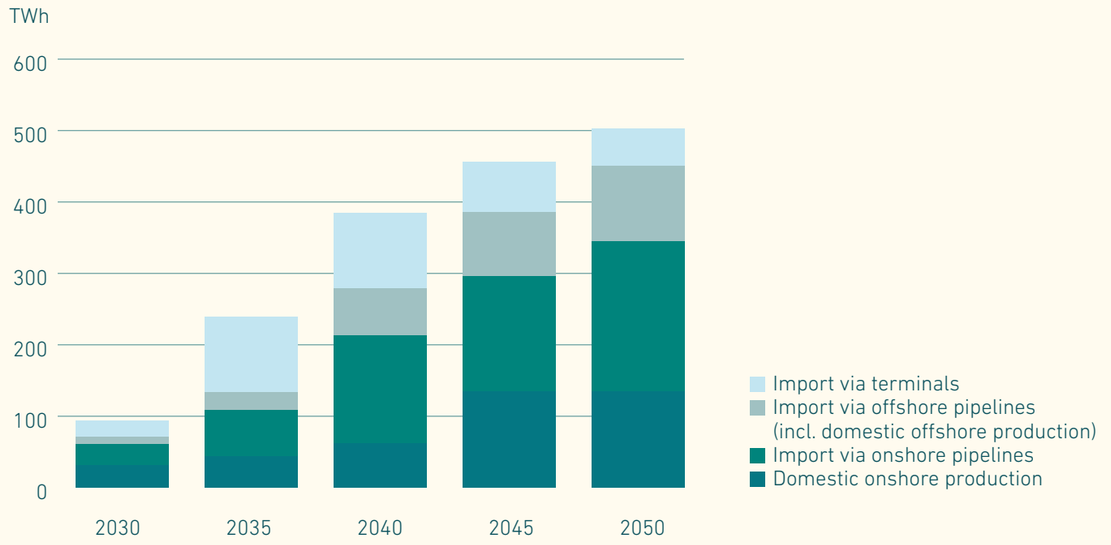

Figure 2 Hydrogen supply development per source in TWh (LHV)

DENMARK
In Denmark the European scenario Distributed Energy describes a hydrogen production capacity rising from 1 GWe in 2030 over 16 GWe in 2040 to 22 GWe in 2050. Further, the Danish hydrogen demand is expected to be limited compared to the production with large export potentials of green hydrogen as a result, Figure 3. The Danish hydrogen production increases considerably after 2030 and in 2040 the production surplus for potential export is approx. 98 TWh rising to 119 TWh in 2050.

For Danish infrastructure planning purposes, the Danish Energy Agency (DEA) develops the Analysis Assumptions, which describes the Danish political ambitions regarding the longterm electricity production and demand, including the electricity demand for Power to X. The assumptions are updated once a year. The latest version is the Analysis Assumptions 2022 (AF22). AF22 foresees a development of electrolysis capacity from 5 GWe in 2030 to approx. 17 GWe in 2040. The development of electrical production capacity grows to approx. 60 GWe in 2040, Figure 4.

Additionally to AF22, the Danish Energy Agency (DEA), Energinet and the Danish gas distribution company Evida have conducted a **market dialogue** between August and October 2022 where Danish PtX players were encouraged to state their interest in hydrogen infrastructure and how a hydrogen infrastructure can best support the development of a PtX industry in Denmark. The market dialogue indicates that, initially, the highest hydrogen production and consumption will be in Western Denmark (Jutland), and that the hydrogen production capacity in Denmark may increase significantly in the period till 2030 with a total capacity of approx. 14 GWe. In the period till 2040 the total electrolysis capacity of 21 GWe has been reported.

UNITS
The amount of hydrogen production can be given both as the electricity demand for hydrogen production – capacity of electrolysers (GWe) – as well as the actual hydrogen amount produced.

The recalculation between those values is based on an assumed efficient factor of 0,68 for the electrolysers.

When the electricity consumption for hydrogen production is shown the units are with an e as in GWe/ GWhe, and when the actual hydrogen production is shown the units are without as in GW/GWh.

When recalculating between energy (GWh) and capacity (GW) it is assumed that the PtX plants have 5.000 full load hours.

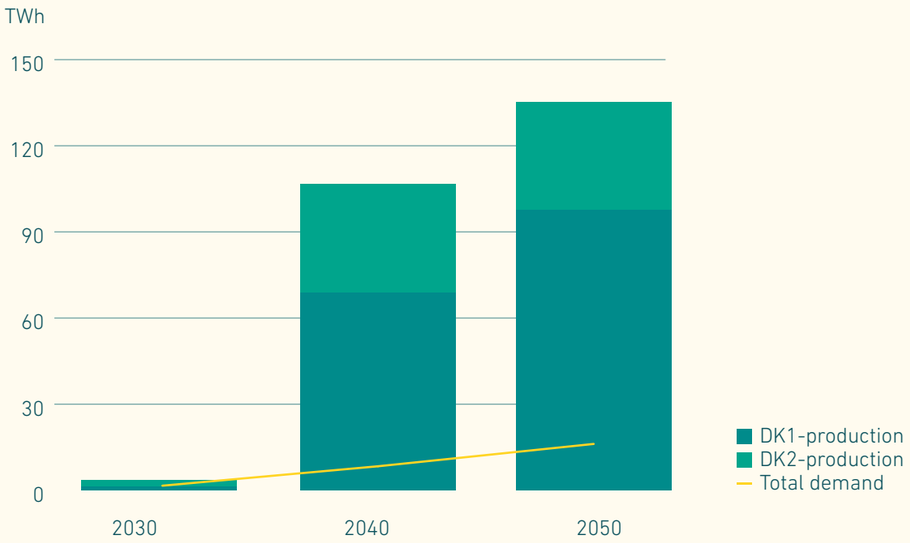

Figure 3 The Danish hydrogen demand and production as predicted in the European scenario Distributed Energy (LHV). DK1 is the western part of Denmark (Jutland and Funen), with connection to the continental Europe, DK2 is the eastern part of Denmark (Zealand).

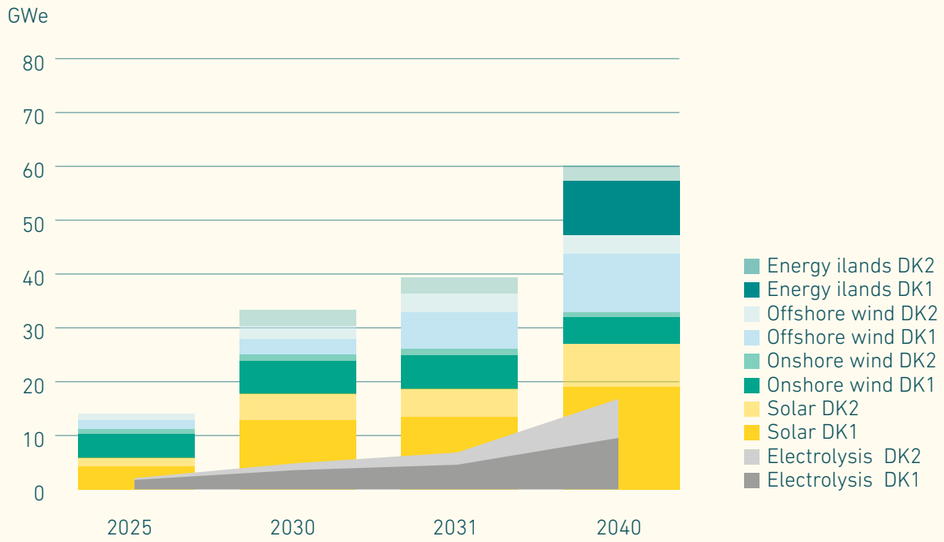

Figure 4 Development in renewable energy sources for power production and electrolysis capacity as assumed in the latest analysis assumptions from the Danish Energy Agency (AF22)

Further, market players indicate that the Danish production could be considerably larger than the domestic usage and many of them expect to sell hydrogen primality abroad via a pipeline infrastructure. Currently signals indicate that up to 90 % of the Danish hydrogen production may be used for export. There is a growing interest in using green hydrogen in Denmark, too. The focus is on e-fuel production. The latest market dialogue showed a large increase in projects intended to produce e-methan in connection with biomethane production.

Based on all the described information and the assumption of a 90 % export share, the potential for the hydrogen export from Denmark may range from 2-7 GWe in a shortterm period rising to 10-14 GWe in 2040. The ranges depend on the scenario considered, Figure 5. These numbers are considered as a basis for the crossborder interconnection planning. The hydrogen production expectations in 2030 from the Distributed Energy scenario is overtaken by reality, as more than 3 GWe electrolysis capacity is already expected to become operational before 2028.

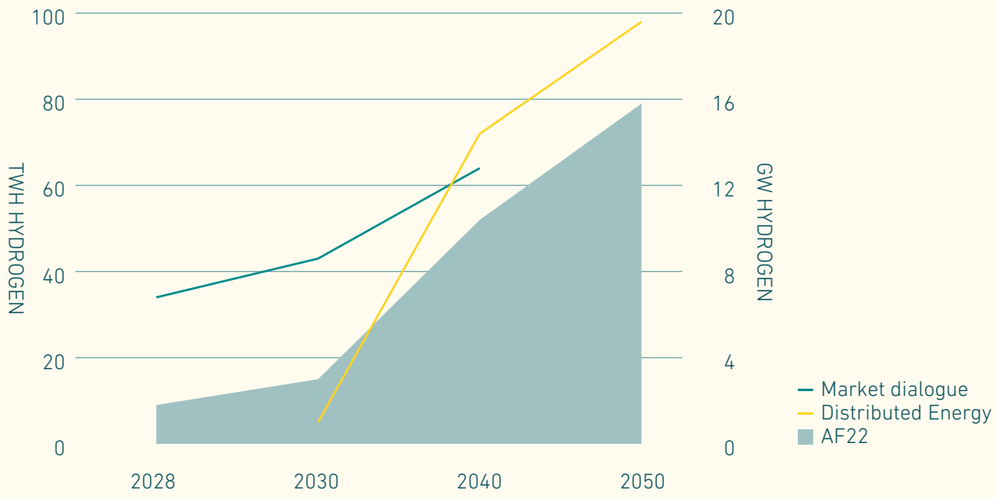

Figure 5 Hydrogen export potentials from Denmark to Germany in different scenarios, when assuming an export potential of 90%.

HYDROGEN INFRASTRUCTURE

The hydrogen infrastructure that is currently on the drawing board, consists of approx. 350 km of pipeline in Denmark and approx. 200 km in Germany.

The Danish system will primarily be established as new infrastructure, while the German system mainly will be based on repurposing of existing methane infrastructure.

The capacity at the cross-border point will be increased stepwise by installing the compression power, based on the market requirements. The Pipeline connection is planned to become operational at earliest by end of 2028.

Projects include a possibility to integrate underground hydrogen storage facilities in Lille Torup (Denmark) and Harsefeld (Germany, Project SaltHy by Storengy). This will support a stable hydrogen delivery to the German users.

INFRASTRUCTURE CONSIDERATIONS

Import of large amounts of hydrogen are most efficiently done by pipeline, provided the energy will be used as hydrogen. Energinet and Gasunie therefore aim to provide an open access, crossborder interconnection between hydrogen production, storage and consumption. It offers the basis and a platform for all involved stakeholders and market participants to market and sell their products or to cover their hydrogen demands.

In the envisaged **European Hydrogen Backbone**, the projects thus play an important role in connecting to other backbones in the neighboring countries and, in doing so, enabling the development of the integrated European hydrogen market in the future. The considered cross-border network is expected to reach from the hydrogen underground storage in Lille Torup in north of Denmark to Heidenau in the area of Hamburg. In Heidenau the crossborder network will be connected to the Hyperlink 1 system of Gasunie, which is a part of the German hydrogen backbone.

In Denmark, Energinet is completing a feasibility study for a hydrogen infrastructure in the western part of Denmark, with connection to the German grid (Danish Backbone West), Figure 6. The study is focused on Jutland as PtX stakeholders expect that hydrogen production will start there due to the access to the large amounts of green electricity generated from on- and offshore wind and solar plants. The routing of the hydrogen infrastructure is expected to follow the large power transformer stations on the west coast of Jutland where hydrogen production is expected, and with connection to the hydrogen storage in Northern Jutland and Germany. The routing will be detailed in the maturation project and in dialogue with the future hydrogen infrastructure users.

In Germany the respective part of the crossborder infrastructure is the project Hyperlink 3. Hyperlink 3 creates a possibility to reach the industrial region Brunsbüttel / Heide, where high hydrogen demand is expected in the future (refinery, fertilizer industry, etc.), as well as future domestic production and consumption sides in Schleswig-Holstein and northern Lower Saxony. Moreover, the project could additionally enable offshore hydrogen imports via an integration of a hydrogen receiving terminal in Brunsbüttel as well as future offshore hydrogen network.

Hyperlink 3 is a subproject of Hyperlink – a hydrogen transport system in the North-West of Germany, developed by Gasunie, which will become an integral part of the national German hydrogen network and European Hydrogen Backbone. After completion of the project Hyperlink will connect the Netherlands, Germany, and Denmark as well as provide access to the offshore hydrogen pipelines and hydrogen receiving terminals. The Hyperlink system will be realized largely through the conversion of existing natural gas transmission pipelines to transport hydrogen and, where necessary, the construction of new pipelines to fill in remaining gaps. Hyperlink will be developed and released in several subprojects between the years 2025 and 2030.

Hyperlink I and II connect the Netherlands (Dutch National Hydrogen Network), Bremen, Hamburg, Hannover and Salzgitter. These two subprojects are nominated for an IPCEI status (Important Projects of common European Interest). Hyperlink IV and V connect Wilhelmshaven (including future potential offshore hydrogen grid landing point and hydrogen import terminals), Rural area and other Hyperlink subprojects. Hyperlink III, IV and V are expected to receive PCI status (applications submitted in December 2022).

Figure 6 The potential hydrogen infrastructure in Denmark and Germany.

PROJECT CHALLENGES AND NEXT STEPS

The market development estimation as well as market dialogue with the stakeholders show that the crossborder hydrogen transport infrastructure is needed already by end of 2028. Moreover, the market signals that a cross border hydrogen infrastructure is a necessary precondition for positive business cases for the majority of the production and industrial consumption projects. Both Energinet and Gasunie are recognizing this and are working together on project development, aiming at commissioning the first part of the infrastructure – including the system in Germany – by end of 2028. The full scope of the infrastructure as shown in Figure 6 is expected to be ready for operation in 2030. Considering the early stage of the hydrogen market development and absence of the European regulatory framework (4th Gas Package is currently under elaboration) this timeline is ambitious. The project comprises the realization of the first hydrogen infrastructure of approx. 550 km. Thus, the timely realization of the project is highly dependent on a good coordination on both sides of the border, alignment between both countries and their concerned authorities as well as smooth processes during the project execution.

An initial assessment of the necessary project milestones shows that due to the time intensive permitting and tendering procedures as well as longer material and equipment delivery periods, investment decisions on both sides of the border are necessary by end of 2024 / beginning of 2025. To be able to take positive investment decisions the financial risks need to be adequately distributed between all interested parties. Binding commitments from network users – capacity bookings or guarantee agreements – are necessary to ensure the future infrastructure utilization.

In the immature hydrogen market, the establishment of all types of investments in the hydrogen value chain (production, transport, and consumption) is highly interlinked and needs to be realized in close alignment. The business cases and positive investment decisions are dependent on the mutual commitments. In case of a positive investment decision for the realization of the transport infrastructure, network operators commit themselves to the project realization and guarantee the availability of the transport infrastructure at a certain point in time, which is the necessary precondition for the investment decisions on the production and consumption side.

Therefore, a transparent and close dialogue between future network operators and network users is necessary to align the investment decisions and reach binding commitments between the parties. As the next step, Gasunie and Energinet plan to intensify the dialogue with the potential network users and conduct a binding commitment process, inspired by an Open Season Process, used in the past to expand the natural gas transport infrastructure. The process will expectedly contain three phases – a prephase, a nonbinding phase and a binding phase. In the prephase network users will be introduced to the process and a consultation on the content as well as prequalification will start. In the nonbinding phase interested and prevalidated parties can address their transportation needs, and in the binding phase, final bids are given prior to heading towards legal binding agreement guaranteeing capacity booking and infrastructure realization. The described process is planned to be launched before the end of 2023 and be finalised during the first half of 2024.

In the preparation to this process the initial technical design of the infrastructure is under reelaboration. Capacity scenarios and their respective costs will be reassessed in line with the current market needs to provide better indication. Operational framework and aligned commercial model are under development. All interested parties are invited to contact Energinet and Gasunie and to provide their input to the described process and underlined assumptions. A successful realization of the project requires close liaison between network operators, (potential) network users, local and national authorities, and others as well as mutual support.

CONTACT ENERGINET

Tonne Kjærsvej 65
7000 Fredericia
Denmark
+45 70 10 22 44

info@energinet.dk
www.energinet.dk

CONTACT GASUNIE

Pasteurallee 1
30655 Hannover
Germany
+49 (0) 511 640 607 0

info@gasunie.de
www.gasunie.de