RIFS DISCUSSION PAPER

Research Institute for Sustainability (RIFS)
Potsdam, April 2023

The Netherlands as a Future Hydrogen Hub for Northwest Europe

Analysing Domestic Developments and International Engagement

Roelof Stam, Coby van der Linde & Pier Stapersma

Part of a series edited by Yana Zabanova and Rainer Quitzow

RIFS POTSDAM

CIEP

Summary

The Dutch government believes hydrogen will play an important role in decarbonizing the energy system. Industry, NGOs and the government work together in the Netherlands to setup low-carbon hydrogen supply chains. The Netherlands is in a good position to make a significant contribution to Europe's low-carbon hydrogen market, thanks to its current role as a European energy hub, large chemical industry, geographic location at the North Sea, offshore wind potential and existing gas and oil infrastructure.

The Dutch national hydrogen strategy predominantly focuses on hydrogen produced via electrolysis from renewable electricity. However, there is also room for hydrogen produced from natural gas or waste gases with CCS, given that this effectively contributes to the development of the broader Dutch hydrogen system, without hampering the growth of hydrogen produced via electrolysis from renewable electricity. In the initial market phase, the Dutch government will prioritize hydrogen supply for the hard-to-abate sectors such as heavy industry and heavy-duty transportation. In later market phases more sectors could be using hydrogen as an energy carrier. The Dutch government has chosen for a combination of obligations and a variety of subsidies schemes, to increase investment security and scale up the low-carbon hydrogen market by 2030.

Internationally the Netherlands aims to position itself as the low-carbon hydrogen hub of Northwest Europe, connecting international exporters and Dutch domestic production at the North Sea with industrial demand centres in Northwest Europe. Acknowledging the scale of the task at hand, the Dutch government is open for partnerships along the whole value chain to work towards an international low-carbon hydrogen market.

Acknowledgement
This discussion paper was developed by the Clingendael International Energy Programme (CIEP) within the framework of RIFS Potsdam's "Geopolitics of the Energy Transformation – Implications of an International Hydrogen Economy" (GET Hydrogen) project.

This Discussion Paper is part of a series of case studies on hydrogen strategies in European and global frontrunner countries. The Discussion Paper series is being edited by **Yana Zabanova** and **Rainer Quitzow** as part of the project "Geopolitics of the Energy Transformation: Implications of an International Hydrogen Economy" (GET Hydrogen) funded by the German Federal Foreign Office.

Federal Foreign Office

Contents

1. Introduction

The Dutch government has recently taken a more active role in the energy transition and therewith the creation of a low-carbon hydrogen[1] economy in the Netherlands. In the Dutch Climate Act of 2019, the government states that it wants to reduce CO2 emissions by 49 per cent by 2030, compared to 1990 levels, and aims to achieve a near 100 per cent reduction by 2050 (Government of the Netherlands, 2019). These ambitious climate targets require drastic changes to the energy system, which is currently based largely on fossil fuels (85 per cent of total final energy consumption) (BP, 2022). Hydrogen can potentially fulfil a 'systemic function' in the future energy system, accommodating intermittent renewable electricity (Clingendael International Energy Programme, 2019). As stated in the 'Dutch Government Strategy on Hydrogen (2020)', the government believes hydrogen will play a crucial role in the energy and feedstock transition, especially in hard-to-abate sectors (Ministry of Economic Affairs and Climate, 2020). The Netherlands have a preference for hydrogen produced via electrolysis from renewable energy but additionally there is also room for hydrogen produced from natural gas with Carbon Capture and Storage (CCS) technology where applicable.

In order to achieve the Netherlands' climate targets while preventing carbon leakage and maintaining its current energy hub function, the Dutch government is working together with the private sector to realize the development of a low-carbon hydrogen market. Industry, NGOs, research institutions and government are cooperating on a large array of projects aimed at realizing a low-carbon hydrogen economy in the Netherlands. Often these projects are of an international character, connecting neighbouring countries, stakeholders in the North Sea region and global industry (Topsector energy, 2020).

This paper will discuss the Dutch hydrogen policy strategy.[2] First the starting position of the Netherlands in the emerging low-carbon hydrogen economy is illustrated, after which a broad overview of the national hydrogen strategy and policy initiatives is given. The last section describes the international approach the Dutch government takes in the emerging low-carbon hydrogen economy.

[1] Low-carbon hydrogen is defined as all hydrogen produced with a significant carbon footprint reduction compared to unabated hydrogen production. This includes hydrogen produced via electrolysis from renewable electricity (green), hydrogen produced from natural gas or waste gases with CCS (blue) and various other 'low-carbon' hydrogen production methods. The Netherlands is an active member of IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy). IPHE is involved in the certification of the carbon footprint of hydrogen produced from different sources and with different technologies to facilitate the development of international trade in low carbon hydrogen. See their publication 'Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen (2022) Available at:
https://www.iphe.net/_files/ugd/45185a_48960ad9b26045c7a082bceb3a192bc7.pdf.

[2] The Dutch hydrogen strategy and policy approach as discussed in the paper is predominantly based on the Dutch Climate Act (2019), the National Hydrogen Programme (2022) and various letters to parliament (e.g. Government Strategy on Hydrogen (2020), Development Transport System for Hydrogen (2022) and Organization and Development of the Hydrogen Market (2022)).

2. The position of the Netherlands in the emerging low-carbon hydrogen economy

The Netherlands is in a strong position to make a significant contribution to Europe's low-carbon hydrogen market thanks to its current role as a European energy hub, substantial chemical industry, favourable geographical location at the North Sea, offshore wind potential, and existing gas and oil infrastructure.

2.1 Energy hub

The Netherlands is home to Europe's largest seaport, the Port of Rotterdam, located at the North Sea and in the Rhine-Meuse-Scheldt delta. With its relatively deep-water port and convenient location, connecting international waters with Northwest Europe, the port of Rotterdam functions as a global hub for international energy trade. The Port of Rotterdam plays an important part and is embedded in the Antwerp-Rotterdam-Rhine-Ruhr-Area (ARRRA), a petrochemical cluster that generates 40 per cent of the total petrochemical output in the EU (Port of Rotterdam, n.d.-b) Significant quantities of energy, among others in the form of crude oil, oil products, coal and gas are imported through Rotterdam daily, and transported via river barges and pipelines to industrial clusters located in Northwest Europe (van der Linde & Stapersma, 2018).

The Dutch government seeks to maintain this hub function in a future renewable energy system. As hydrogen potentially becomes a globally traded commodity and industrial demand for low-carbon hydrogen in Northwest Europe increases, the Netherlands is in a unique position to contribute to the hydrogen supply chain by both producing and importing low-carbon hydrogen and providing a gateway to Northwest Europe (Ministry of Economic Affairs and Climate, 2020; Port of Rotterdam, N.D.-a). The offshore wind potential in the Dutch part of the North Sea is also an important incentive for the development of a low-carbon hydrogen economy.

In addition, facilities at Groningen Seaport in the north of the country are developing into a landing point for offshore wind and conversion into hydrogen. These facilities are closely located to similar German plans to develop their side of the Ems Delta, creating a potential new conversion cluster. A similar development is ongoing in the south of the country, on the banks of the Scheldt River and along the canal from Terneuzen to Ghent in Belgium.

2.2 Industry

The Netherlands has a relatively energy intensive economy due to its large refining and petrochemical sector and other economic activities that benefitted in the past from the availability of abundant natural gas, including greenhouse-based agriculture and horticulture, and fertilizer production. Hydrogen is already a widely used commodity in the chemical, refining and fertilizer industry. It plays a multidimensional role in these industries, as it is a by-product in some processes, while being an essential feedstock or a potential alternative energy carrier in others.

With an estimated 1.5 million tonnes per year, the Netherlands is the second largest hydrogen producer in Europe, after Germany (TNO, 2020). As such, the Netherlands has extensive experience in the safe production, transportation, storage, and consumption of hydrogen in industrial settings. Currently, most hydrogen produced in the Netherlands is created via steam methane reforming using natural gas (862,000 tonnes per year, most of the remaining of hydrogen is produced with oil and residual (refinery) gasses (574,000 tonnes per year) (TNO, 2020). Approximately 10 per cent of the Dutch gas consumption is used to produce hydrogen, emitting significant amounts of CO2 (Ministry of Economic Affairs and Climate, 2020).

In addition to hydrogen production via electrolysis from renewable energy, hydrogen from natural gas and waste gases with CCS provides a relatively quick solution to decrease emissions considerably and plays a role in the Dutch national carbon reduction strategy (Ministry of Economic Affairs and Climate, 2020). An example of an initiative to reduce carbon emissions in current hydrogen production is the H-vision project in Rotterdam, which aims to produce low-carbon hydrogen from natural gas and residual refinery gasses. In this project, CO2 would be captured and either stored in empty gas fields under the North Sea or used as feedstock for basic chemicals such as methanol. The hydrogen would be used as input for the refinery process (H-vision, n.d.). The transportation and storage of CO2 would be facilitated by Porthos.

Porthos stands for Port of Rotterdam CO2 Transport Hub and Offshore Storage and is the flagship CCS project in the Netherlands. However, the Porthos project is at risk of delays due to a lawsuit filed by Mobilisation for the Environment (MOB) against the state, concerning the nitrogen the project is expected to emit during its construction. The Netherlands is currently struggling with a 'nitrogen crisis'. Excessive amounts of nitrogen emissions from agriculture, industry and transportation threaten the country's biodiversity. Although these emissions have decreased significantly over the years, they continue to pose a threat to the environment. In an interim ruling issued on 2 November 2022, the court concluded that the nitrogen construction exemption used for the Porthos project does not comply with European Nature Conservation Law and may not be used for the construction of the project. Therewith, Porthos is delayed but is not yet off track. An individual assessment of the nitrogen impact must be made for the project (Raad van State, 2022).

On 9 December 2022, the Ministry of Climate and Energy published a letter to parliament in which it declared that it would temporarily assume liability for financial risks related to this project, pending the final verdict (Ministry of Economic Affairs and Climate, 2022a). The government considers the carbon reduction that Porthos could provide (2.5 million tonnes CO2 per year) to be crucial to its efforts to achieve the 2030 climate goals. In order to prevent delays or possible cancellations, it is necessary that Porthos continues the tendering procedures already initiated. Therefore the government aims to guarantee financial obligations for a maximum amount of 175 million euros up until the end of 2023 (Ministry of Economic Affairs and Climate, 2022a).

However, the interim ruling has significant implications for the construction industry in general, as it means that in the future the compliance of individual construction projects with the requirements of the Nature Conservation Act will need to be assessed. This will lead to considerable delays in permitting processes and to delays in the construction of homes, infrastructure and energy projects, creating a serious obstacle to the energy transition in the Netherlands (Meijer, 2022).

2.3 North Sea

The Netherlands' location on the North Sea is well-suited for the production of hydrogen via electrolysis from renewable energy. The Dutch part of the North Sea covers an area of about 58,000 km2 (Government of the Netherlands, 2016). With its favourable wind conditions, relatively shallow waters, good access to ports and energy intensive industries, which are largely situated or alternatively

well connected to coastal areas, the North Sea is very suitable for offshore wind power. Some of this wind energy could be used to produce hydrogen.

There are various projects underway to start producing hydrogen through electrolysis at or near the North Sea. For example, Shell has recently taken the final investment decision on Holland Hydrogen 1, a 200 MW electrolyser project in Rotterdam on the Second Maasvlakte (Shell, 2022). They intend to produce hydrogen using wind energy from the offshore wind farm Hollandse Kust Noord. Another example is H2opZee, a project in which Germany's RWE and UK-based Neptune Energy join forces to accelerate hydrogen production in the Dutch North Sea. This demonstration project will have an electrolyser capacity of 300 to 500 MW and will use existing pipelines to transport hydrogen produced at sea to land (RWE, n.d.). Another project is NortH2, an international consortium consisting of Equinor, ENECO, Gasunie, Groningen Seaports, RWE and Shell Nederland, endorsed by the Groningen provincial authority, which is currently investigating the feasibility of large-scale production, storage and transmission of hydrogen in Groningen. NortH2 aims to convert offshore wind energy into hydrogen through electrolysis in Eemshaven to supply industry with 4 GW of hydrogen by 2030 and upscale to more than 10 GW by 2040 (NortH2, n.d.).

2.4 Gas legacy assets

With the discovery of the Groningen gas field in 1959, the Netherlands became the number one natural gas producer in Europe. This stimulated the development of an extensive high-quality natural gas network connecting the Netherlands and parts of Belgium, France, and Germany. In addition to this, it was the Dutch state that established the institutional arrangements for a European gas market, from which lessons for hydrogen can be drawn. These public-private partnerships made the development of natural gas infrastructures and natural gas markets a great European success (Correljé et al., 2003).

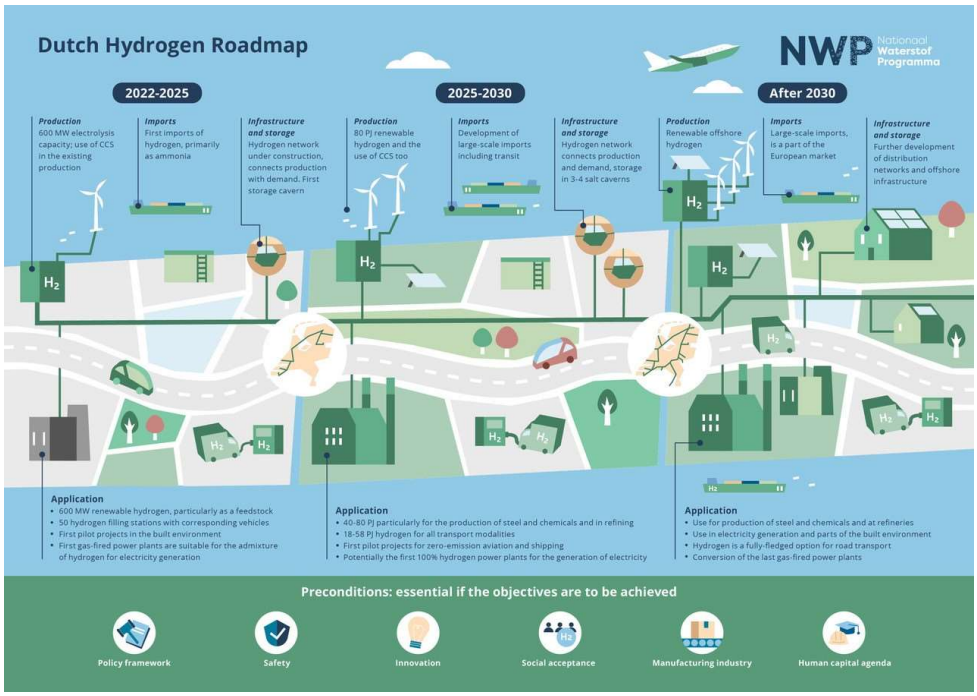
Although the Groningen gas field was long one of the largest onshore gas fields in the world, its supplies are finite. Therefore, in the 2000s, in order to diversify away from a predominant focus on national production, the concept of a gas hub strategy was implemented, partly shifting the focus from national production to imports. This resulted in the construction of necessary infrastructure such as import terminals and storage facilities. The gas hub strategy has proven valuable in this time of geopolitical uncertainty as it enables European countries to replace Russian flows with new liquefied gas supplies from overseas. Furthermore, the repurposing potential of this infrastructure presents a favorable starting position for the future low-carbon hydrogen economy.

On 26 September 2022, well before its anticipated depletion, Hans Vijlbrief, State Secretary for the Extractive Industries, stated that the Groningen gas field would be put on 'pilot light' as of 1 October 2022 due to the seismic risk caused by production activities (Government of the Netherlands, 2022a). This means that a minimum amount of gas will be extracted from the field so that existing wells and infrastructure can continue to operate, ensuring that the field is still available as spare capacity in case of a severe disruption in low calorific natural gas supplies or an emergency in the Netherlands or neighbouring countries. The Groningen field will close completely in 2023 or 2024, if security of gas supply can be ensured around that time. Due to the planned closure of the Groningen field and the expected general decline of natural gas demand over the coming years, gas infrastructure will become available for repurposing to transport hydrogen production (Government of the Netherlands, n.d.). The Netherlands has two natural gas pipeline systems, one for high calorific gas and one for low calorific (Groningen quality) gas. With demand for low calorific gas decreasing some spare pipeline capacity is already being converted to carry hydrogen. In 2021 the government decided to refurbish gas pipelines to create the 'Dutch hydrogen backbone' connecting the Dutch industrial clusters (European Hydrogen Backbone, n.d.). This will be further discussed later in this paper.

3. National hydrogen strategy and policy initiatives

In the Dutch Climate Agreement (2019) the low-carbon hydrogen economy was identified as a key part of the carbon emission reduction strategy (Government of the Netherlands, 2019). Central to the Dutch hydrogen strategy is the National Hydrogen Programme (2022), which originated from the Dutch Climate Agreement. The main task of the National Hydrogen Programme, a public-private partnership, is to investigate and stimulate the contribution of hydrogen to the realization of the energy transition. In 2022 its focus was on creating a Hydrogen Roadmap for the Netherlands together with stakeholders from the hydrogen sector. The Roadmap proposes low-carbon hydrogen targets for 2030 and describes what actions are necessary to achieve them. Figure 1 provides a schematic overview of the Hydrogen Roadmap, for more detailed information please see the Hydrogen Roadmap report (National Hydrogen Programme, 2022). The Dutch government takes an integrated approach to developing hydrogen value chains, focusing on production, import, transportation, storage, as well as the demand side, potential revenue models and on how to deal with safety and regulatory issues (National Hydrogen Programme, 2022; Netherlands Enterprise Agency, 2021a).

Figure 1: Schematic overview of the Dutch Hydrogen roadmap



Source: National Hydrogen Programme (2022). Routekaart waterstof. Available at: https://www.nationaalwaterstofprogramma.nl/documenten/handlerdownloadfiles.ashx?idnv=2339011

3.1 Cluster-based energy strategy

Industry in the Netherlands is highly concentrated in regional clusters, due to economies of scale, location, cooperation opportunities and infrastructure. These clusters are identified as: Rotterdam-Moerdijk, the North Sea Canal Area (Noordzeekanaalgebied), the Northern Netherlands (Noord Nederland), Chemelot, Zeeland/West-Brabant and 'other industries' (a sixth cluster which contains remaining industries spread across the country) (Programme Sustainability Industry, n.d.). The government has set up Regional and Cluster-based Energy Strategies (RES & CES) to reduce carbon emissions in Dutch industry. The strategies focus on matching future supply and demand of renewable energy and on obtaining a better understanding of the necessary infrastructure. Additionally, the Dutch government created the 'Multi-year Infrastructure Energy and Climate programme' (MIEK) in 2021. MIEK describes the energy and raw material infrastructural projects that the cabinet plans to implement to accelerate the transition in the industry (Netherlands Enterprise Agency, 2021b). Dutch industry is characterized by strong integration and cooperation between companies within these industrial clusters and an open consultation structure among private sector players. These unique characteristics create an environment in which innovation can flourish, making the Netherlands a good 'testing ground' for pilot projects. However, it is important to note that the investment climate has recently become less attractive due to changes in the corporate fiscal regime and nitrogen legislation. National nitrogen policy, introduced to reduce nitrogen emissions and protect biodiversity, make it more difficult and in some cases impossible to get building permits for infrastructural projects in the Netherlands, including projects necessary for the energy transition, like the aforementioned Porthos project.

3.2 Prioritized end-use sectors

The Dutch government believes that clean molecules and in particular low-carbon hydrogen will be necessary for the decarbonization of hard-to-abate industries, seasonal storage, and applications where electrification is not a viable option (Ministry of Economic Affairs and Climate, 2020). In the initial market phase, the supply of hydrogen to heavy industry and for heavy-duty transportation will therefore be prioritized.

Big industrial players are starting to prepare for a hydrogen future. For example, Tata Steel has announced plans to produce steel in the Netherlands using Direct Reduced Iron technology, a process in which iron ores are reduced using natural gas or hydrogen, instead of coal. Tata intends to commence operations before 2030 (Tata Steel, 2021). Shell aims to supply the Shell Energy and Chemicals Park Rotterdam with hydrogen produced via electrolysis in the Holland Hydrogen 1 plant using the HyTransPort gas pipeline in 2025. As the hydrogen heavy-duty truck market grows, Shell also plans to supply hydrogen as a fuel for commercial road transportation (Shell, 2022).

When the low-carbon hydrogen market moves into a later development phase, more sectors could be using hydrogen as an energy carrier. Besides initiatives in the industry and mobility sectors, plans for the first pilot projects in the electricity sector, built environment and agricultural sector are currently being developed; For an extensive list of 165 projects, see the Dutch National Hydrogen Programme (National Hydrogen Programme, n.d.-c; National Hydrogen Programme, n.d.-d).

3.3 The role of different forms of hydrogen production

The Dutch government predominantly focuses on hydrogen produced via electrolysis from renewable electricity and hydrogen made from sustainable biogenic raw materials. Furthermore, there is also room for hydrogen produced from natural gas or waste gases with CCS, as long as this optimally contributes to the development of a broader hydrogen system, without hindering the growth of hydrogen produced via electrolysis from renewable electricity. Hydrogen from natural gas or waste gases with CCS is seen as a cost-effective way to help achieve the 2030 climate targets (National Hydrogen

Programme, 2022). However, the current high price of natural gas might hinder the realisation of these plans. In the long-term the focus will be on technologies that reduce emissions to net zero and replace fossil fuels with biotic and recycled raw material (Government of the Netherlands, 2019).

In the Dutch Climate Agreement of 2019 a target of 4 GW of electrolyser capacity for 2030 was agreed upon (Netherlands Enterprise Agency, 2021a). However, as the Netherlands is determined to reduce its dependence on Russian gas, following the invasion of Ukraine, two coalition parties (D66 and VVD) proposed to double the already ambitious 2030 electrolyser capacity target to 8 GW (D66 & VVD, 2022). Although hydrogen will not play a role in securing energy supplies soon, it is widely viewed as an important building block for the development of domestic energy carrier production and fuel diversification to increase energy security in the future.

Besides domestic production, the Dutch government set an additional import target of 4 GW[3] of low-carbon hydrogen in 2030. The Netherlands has a rather energy intensive economy combined with a relatively small land area. As hydrogen is expected to fulfil a significant part of the total future energy demand, especially in industry and transportation, it is considered unrealistic to produce all necessary hydrogen domestically (National Hydrogen Programme, n.d.-a). As hydrogen becomes a globally traded commodity, dependence on hydrogen comes with security of supply risks of its own. The Dutch government recognizes the importance of setting up measures to ensure the security of supply of imported hydrogen and commissioned the Clingendael International Energy Programme (CIEP) to conduct research on managing the future security of low-carbon hydrogen supply (Clingendael International Energy Programme, 2022). Finding the right balance between the development of domestic production and imported flows of low-carbon hydrogen is crucial for a strong and secure hydrogen economy in the Netherlands.

3.4 Policies for the use of low-carbon hydrogen in the industrial sector

The Dutch government has opted for a combination of obligations and subsidies to increase investment security and scale up the low-carbon hydrogen market by 2030 (Ministry of Economic Affairs and Climate, 2020; National Hydrogen Programme, n.d.-b). Currently, with regard to obligation-based policy, the government is exploring possible options to introduce a purchase obligation for low-carbon hydrogen in industry, which would come into effect on 1 January 2026 (National Hydrogen Programme, n.d.-b). This would help ensure that the Netherlands can meet the 'expected' binding target of 50 per cent renewable hydrogen, from the Fit-for-55 package, for all hydrogen used in industry by 2030 (Article 22a from the revision of RED II) (European Parliament, 2021). A purchase obligation would provide hydrogen producers with the necessary demand security to make large-scale investments. Furthermore, it would reduce the single dependence on subsidy schemes to achieve a (potential) future binding hydrogen target in industry (Ministry of Economic Affairs and Climate, 2020).

Subsidies will provide a targeted means to adjust the market and offset part of the additional costs that come with the transition to low-carbon hydrogen as energy carrier. The financial support schemes are tailored to the various phases of the innovation development process. They are broadly subdivided into the following three categories in the Dutch Government Strategy on Hydrogen: subsidies for applied research and innovative pilot projects, scaling up projects with temporary operating cost support, and roll-out of full-scale projects via the SDE ++ (Ministry of Economic Affairs and Climate, 2020).

As of 2020, the Stimulating Sustainable Energy production and Climate Transition (SDE++) scheme,

[3] This is a somewhat unusual unit to quantify hydrogen imports and can be interpreted in various ways. The 4 GW target could represent 1 million tonnes of hydrogen per year ((4 [GW] * 8760 [h]) / 33 [MWh/tonnes]), however, it is not completely clear what the Dutch government means with this target.

one of the most important subsidy schemes for realizing large-scale renewable energy or CO2 reduction projects, includes low-carbon hydrogen projects (Netherlands Enterprise Agency, 2021c). The SDE++ is an operating subsidy scheme. Subsidies are given to technologies that provide the most cost-effective renewable energy or carbon emission reduction. The budget of the SDE++ 2022 has recently been increased to 13 billion euros. The maximum budget for CCS in industry for the SDE++ scheme has been raised for 2022 but will gradually be phased out in the transition to a climate-neutral industry over the years.

As electrolyser projects are currently not the most cost-effective way to reduce carbon emissions, so far they have barely obtained any funding through the SDE++ scheme. Therefore, the Dutch National Growth Fund set up 'greengrowthcapacityNL' (groenvermogenNL) to scale up electrolyser projects and green chemistry ecosystems in the Netherlands. 838 million euros from the National Growth Fund was made available for the first two rounds of projects (Topsector Energy, 2022).

4. International approach

Internationally the Netherlands seeks to position itself as the hydrogen hub of Northwest Europe, connecting Dutch domestic production at the North Sea and international exporters with users in industrial clusters in Northwest Europe. The Port of Rotterdam is currently the most important energy corridor to Northwest Europe and aims to leverage its current position to continue this role in the future hydrogen value chain (Ministry of Economic Affairs and Climate, 2020). Zeeland port and Eemshaven are also developing hubs based on offshore wind landed in these ports. Nevertheless, Denmark and Belgium have expressed similar ambitions, while also Germany is keen to develop the Wilhelmshafen and Ems delta region for hydrogen hubs. They could be viewed as competitors, however there are also many opportunities for cooperation among these ports and countries. The regional ecosystem of various ports in Europe will help attract global suppliers, for example. Given the scale of the task, the Dutch government views cooperation as essential and is looking for partnerships along the whole value chain on a local, regional and international scale (RVO, 2021).

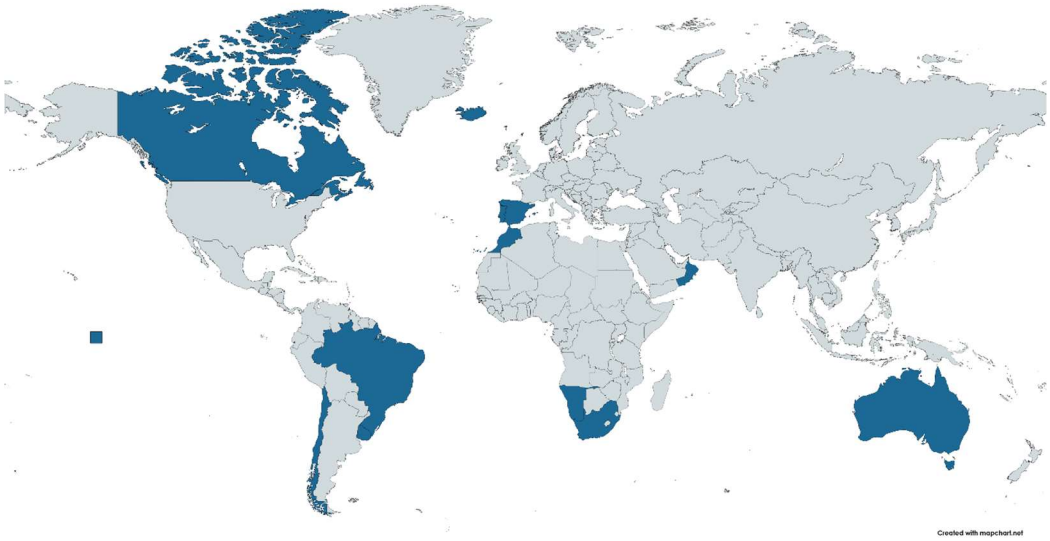
4.1 Bilateral partnerships

Dutch bilateral foreign policy in this field focuses predominantly on cooperation with neighbouring countries and establishing trade relationships with future exporters of low-carbon hydrogen. Together with the German and Belgian governments, the Dutch government is investigating opportunities to collaborate in the production, transportation and usage of hydrogen. Developments in Germany are especially relevant to the Netherlands, as North Rhine-Westphalia intends to import half of its future hydrogen demand from or via the Netherlands (Innovation Origins, 2021). An example of current Dutch-German collaboration is the HY3 project, which recently completed a feasibility study (March 2022). They reviewed how Dutch and German offshore wind energy could be used to produce hydrogen, which would then be transported using existing Dutch gas pipelines to Dutch and German industrial clusters (HY3, n.d.). Another example is the German H2Global import initiative which the Netherlands intends to join as the first governmental partner (Schaps, 2022). Together with the Port of Hamburg and Duisburg, the Port of Rotterdam is seen as a key delivery location for the international hydrogen flows attracted via the H2Global scheme. Participating in the initiative is important to the Netherlands as it aims to play a role in the development of the first international hydrogen value chains.

As it is of strategic importance to the Netherlands to maintain its current energy hub function in the future low-carbon hydrogen economy, the government and industry are actively pursuing potential import relationships with future prospective exporting countries. It is expected that the first import flows will come from current fossil fuel exporters, such as countries in the Middle East and North America. This is due to the relatively large potential for renewable electricity and the existing networks, infrastructure and expertise that can be utilized in these regions. Shortly thereafter, imports from European countries such as Portugal and Spain are expected to follow. The initial volumes will be small, however, in the future the Netherlands expect to import hydrogen from a growing number of countries within and outside of Europe (National Hydrogen Programme, 2022). The Netherlands was actually the first country to install a dedicated hydrogen envoy and has so far set up exploratory studies and established MoU's with Namibia, Chili, South Africa, Canada, Uruguay, Oman, Morocco, Iceland, Spain, Portugal, Brazil and Australia (see figure 2) (IRENA, 2022; Port of Rotterdam, n.d.-a).

Two prominent European partnerships should be mentioned here: Cepsa, a Spanish multinational energy company, and the Port of Rotterdam have recently signed an MoU for a hydrogen corridor connecting Northern and Southern Europe. The corridor is expected to be operational from 2027 and will transport hydrogen derivatives produced in Spain from the Port of Algeciras to the Port of Rotterdam in the Netherlands. The project is expected to be able to transport 4.6 million tonnes of hydrogen annually to Northwest Europe in 2030 (Cepsa, 2022). Furthermore, a consortium consisting of ENGIE, Shell, Vopak and Anthony Veder, has agreed to conduct an exploratory study on the production and transportation of liquified hydrogen from Portugal to the Netherlands, with the aim to start delivering liquid hydrogen from the Port of Sines to Rotterdam no later than 2027 (Port of Rotterdam, 2022b).

Figure 2: Dutch exploratory studies for cooperation and MoU's with potential future exporting countries



Based on data from Port of Rotterdam and IRENA, created with mapchart.net

4.2 Multilateral partnerships and political dialogue

Besides various bilateral partnerships, the Netherlands is also involved in numerous multilateral partnerships, fora and initiatives. These include: the Clean Energy Ministerial (CEM), which the Netherlands co-leads together with Canada, the United States, Japan and the European Commission (Clean Energy Ministerial, n.d.); Mission Innovation (MI) and the International Partnership for Hydrogen Fuel Cells in the Economy (IPHE), in which the Netherlands is an active member and participates in R&D-related initiatives (Ministry of Economic Affairs and Climate, 2020; Mission Innovation, n.d.); and Hydrogen Europe, where the Netherlands is involved in projects such as HyLAW, focused on the removal of legal barriers to the deployment of hydrogen applications, and JIVE2, a joint initiative for hydrogen vehicles in Europe (Hydrogen Europe, n.d.).

Although the Netherlands is an effective participant in the global dialogue and partnership initiatives at various global fora, the main focus of the Dutch international hydrogen strategy is on Europe (Ministry of Economic Affairs and Climate, 2020). European collaboration is seen as crucial to establishing the first international supply chains, as it increases diversification and enables risk sharing of potential dependencies. The Dutch government therefore supports and will actively participate in the development of the Green Hydrogen Partnerships, import corridors and the Global European Hydrogen Facility envisioned by the EU (Ministry of Economic Affairs and Climate, 2022c).

According to the Government Strategy on Hydrogen, some of the most important ways of engagement in political dialogue for hydrogen policymaking and cooperation in Europe – besides bilateral contact with neighbouring countries – are assumed to be:

- Continued communication with the European Commission about EU hydrogen policy concerning standards for safety, quality, flexible market regulations, sustainability, blending of hydrogen in existing natural gas networks, and innovation support.
- Participation in the Pentalateral Forum, consisting of the Benelux, Germany, Austria, Switzerland and France. Here, Austria and the Netherlands have initiated the development of common standards, market regulations, and market incentives prior to the EU discussion, calling on the European Commission to lobby for common global standards on sustainability. Efforts to establish homogenous levels of hydrogen-blending and ensure interoperability between hydrogen networks in Europe are also on the agenda (Pentalateral Energy Forum, 2020).
- Cooperation with North Sea countries: The North Sea wind power potential is seen as an essential source of energy for the production of hydrogen in the coming decades. The Netherlands intends to cooperate with North Sea countries through projects like the Sea Wind Power Hub, which aims to harness the North Sea's power potential (Clingendael International Energy Programme, 2021).
- Implementation of Important Projects for Common European Interest (IPCEI) focused on hydrogen: On 15 July 2022, the European Commission approved IPCEI Hy2Tech, the first IPCEI to support R&D in the hydrogen technology value chain. The project was initiated and prepared by the Netherlands and fourteen other member states (European Commission, 2022). The Dutch government recently made 1.385 billion euros available for IPCEI hydrogen projects (Government of the Netherlands, 2022b; Ministry of Economic Affairs and Climate, 2020).
- One of the most discussed policy topics regarding hydrogen in Europe have been the Delegated acts and specifically the additionality requirements. This has also been a controversial topic in the Netherlands, where it has been met with both praise and opposition. Rob Jetten, Dutch Minister for Climate and Energy Policy, stated on 29 June 2022 that the proposed rules in the delegated acts overall seem to provide the necessary regulatory space for the Dutch hydrogen ambitions (Ministry of Economic Affairs and Climate, 2022c). He argued that the regulatory proposition provides enough flexibility for short-term projects, while ensuring that over the long-term hydrogen production will not come at the expense of extra renewable electricity on the grid. Although the Dutch government agreed with the overall idea of the delegated acts, they provided some technical feedback to the Commission on the proposed regulations. See the document "Dutch reaction on European consultation delegated acts renewable hydrogen" for a detailed overview of the feedback (Ministry of Economic Affairs and Climate, 2022d).

Furthermore, there has been considerable pushback recently on the proposed regulations in the Dutch private sector, as companies fear that the regulations are too stringent for the initial phase of market development and are more likely to hinder than enable the low-carbon hydrogen economy from getting off the ground (Clingendael International Energy Programme, 2022). The US Inflation Reduction Act poured fuel on the fire, stirring fears that the combination of strict regulations in the EU and favourable subsidy schemes in the US might cause considerable industry displacement from the EU to the US, creating more demand uncertainty.

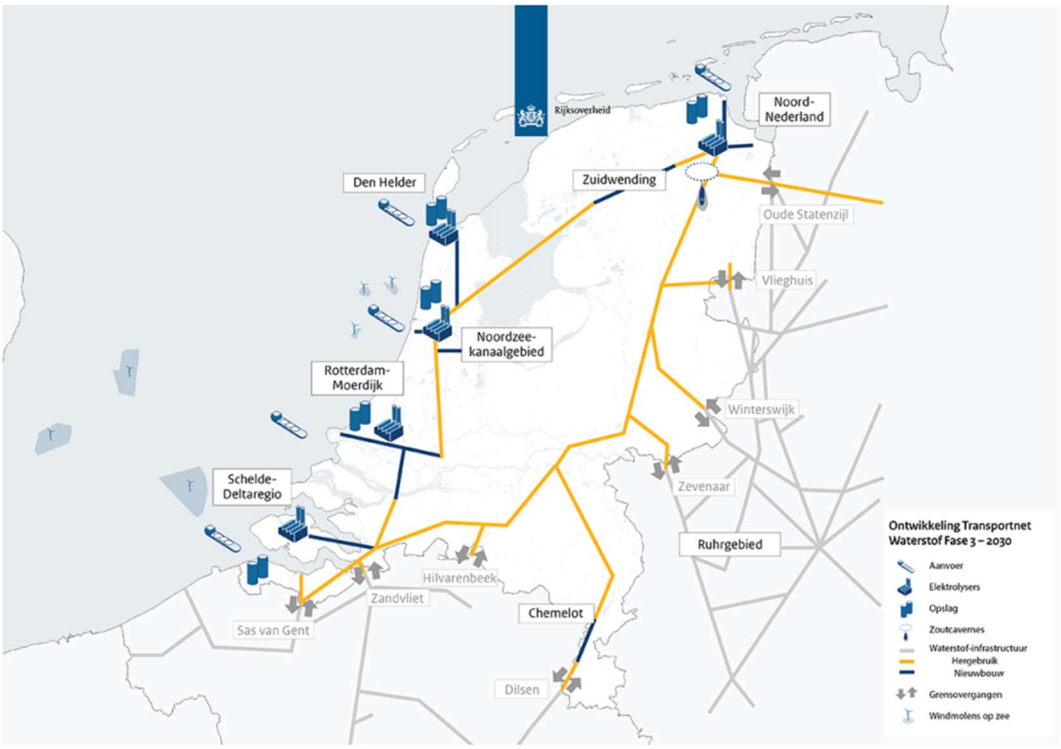
4.3 Shaping hydrogen infrastructure

In June 2021 Gasunie, the Dutch state-owned natural gas infrastructure and transportation company, received a formal mandate from the Ministry of Economic Affairs and Climate Policy to commence the development of a national hydrogen transport network (the Dutch hydrogen backbone). Gasunie currently operates and owns about 11,700 km of gas pipelines, of which approximately 8,700 km are

located in the Netherlands and 3,000 km in Germany (European Hydrogen Backbone, n.d.). The Dutch hydrogen backbone will largely be based on repurposed gas infrastructure and could be complete before 2027. The network will connect the five large industrial hubs in the Netherlands with storage facilities, overseas import, and export to Belgium and Germany (see figure 3). The Dutch hydrogen backbone could have a capacity of approximately 10-15 GW by the end of 2030. The development of the network will take place in multiple phases, a flexible and adaptive approach will be used, based on the needs and development of the hydrogen market (Ministry of Economic Affairs and Climate, 2022b).

Currently HyXchange is being developed, which is a trading platform for hydrogen transported through the Dutch hydrogen backbone, including global import flows and neighbouring countries (HyXchange, n.d.). For this hydrogen exchange to function properly, an open accessible transport infrastructure, a diverse supply of hydrogen and a dependable trading platform are needed. Next to the exchange, long-term contracts are expected to play an important role in the initial phase of market development as the number of suppliers and customers will be limited in the beginning (Clingendael International Energy Programme, 2019).

Figure 3: The Dutch hydrogen backbone



Source: Ministry of Economic Affairs and Climate (2022). Letter to Parliament on the transportation network for hydrogen. Available at: https://open.overheid.nl/repository/ronl-5c57a9ba35fa907dcc805ca0da463dc33b036bb8/1/pdf/ontwikkeling-transportnet-voor-waterstof.pdf

Besides the Dutch hydrogen backbone, the Delta Corridor, a key infrastructural project for the Netherlands to secure its future position as a European energy hub, is currently being developed. After the completion of an initial feasibility study the project is now entering a second phase, to do a more detailed feasibility study, for which the necessary funding has been obtained. In this initiative the

private sector has the lead but is working closely with the EU and the Dutch and German governments. The supporting companies currently consist of the Port of Rotterdam, Shell, BP, Thyssenkrupp, LyondellBasell, HeidelbergCement, Attero and Chemelot (Port of Rotterdam, 2022a). The intended project consists of a bundle of pipelines between the Port of Rotterdam, Chemelot, and the German Rhineland Region.

The pipeline network is scheduled to enter operation in 2026. It will connect large inland industrial clusters in the Netherlands and Germany with branches along the entire network, providing access to low-carbon hydrogen and CCS capacity (see figure 4). It will supply hydrogen to industrial hubs across, Moerdijk, Geertruidenberg, Chemelot and North Rhine-Westphalia (Gelsenkirchen, Cologne and wider areas). Additionally, in the future the Delta Corridor could also connect industrial hubs in Belgium and further into Germany. The capacity will be based on and grow with demand in Northwest Europe.

Figure 4: **The Delta Corridor**

Overzichtskaart van de beoogde Delta Corridor

Source: MIEK (2021). MIEK overview 2021 Multiyear programme Infrastructure Energy and Climate. Available at: https://www.rijksoverheid.nl/documenten/rapporten/2021/11/26/meerjarenprogramma-infrastructuur-energie-en-klimaat---overzicht-2021. Last accessed on 08.12.2022

Lastly, Gasunie is actively participating in the European Hydrogen Backbone initiative, working together with other European network operators on connecting EU member states with an intercontinental hydrogen network. The Netherlands maintains close contact with Germany and Belgium regarding the potential interconnections, development of the hydrogen network and other possibilities for cooperation.

4.4 Anticipating the stages of development in organising the low-carbon hydrogen economy

The Dutch government supports the proposals made by the European Commission regarding harmonized rules for the development of a single European market for hydrogen (Ministry of Economic Affairs and Climate, 2022b). However, based on a recent study commissioned by the government from the Clingendael International Energy Programme (CIEP), the regulatory framework may be a mismatch for the initial stages of hydrogen market development (Clingendael International Energy Programme, 2022). The European Union intends to regulate hydrogen in the same way as the natural gas market is regulated today, with legal separation between networks, production and distribution. This model has shown to work relatively well in mature gas markets with various suppliers and buyers operating in the market. However, legal separation might frustrate the hydrogen economy in the first phases of market development as it could hinder supply as well as demand security in a market with only few participants (Clingendael International Energy Programme, 2019).

During the development of the oil and gas industry, supply chains (production, transportation, and distribution) were built by vertically integrated oil companies in consortiums and public-private partnerships. In order to reduce investment risks for large infrastructural projects like oil and gas exploration and extraction, security of demand is essential. Vertical integration provides the necessary demand security to significantly decrease the risk of oil and gas production investments as well as supply security for buyers. Similar investment securities are necessary for companies that intend to participate in the future low-carbon hydrogen economy (Clingendael International Energy Programme, 2022). The Dutch government is aware that it might be wise to draw lessons from the development of the world oil and gas markets, and provide the regulatory space necessary for companies that are willing and able to set up the supply chains to kickstart the hydrogen economy.

5. Conclusions

The Netherlands is prepared to be among the driving forces shaping the European low-carbon hydrogen economy. This is shown by the government's hydrogen strategy and established subsidy schemes, but more so by the many hydrogen projects that have been announced and first final investment decisions that have been taken recently. An international low-carbon hydrogen economy presents an opportunity for the Netherlands to continue its role as energy corridor to Northwest Europe in a future sustainable European energy system. The Netherlands can contribute to the decarbonization of the continent by connecting industrial clusters in neighbouring countries with hydrogen from international markets. However, nitrogen legislation, lack of available space, and labour market constraints are among the various issues that could yet delay or hinder the development of the low-carbon hydrogen industry in the Netherlands.

Internationally, the Netherlands focuses on cooperation, especially with neighbouring countries. Cooperation with Germany plays a particularly prominent role, especially as a significant share of German demand will have to be met via imports that enter Europe through the Netherlands. However, coordinating timing and coherence along the emerging value chain presents significant challenges. The ability to scale up production and imports will depend, among other things, on whether the necessary infrastructure, regulations, and modifications in the manufacturing industry, are in place. Intensive cooperation between all players in the chain, both nationally and internationally is required to implement a policy framework that will lead to investments in the short-term.

The Dutch government fully supports setting up harmonized rules for the development of the EU hydrogen market. However, the natural gas market model currently proposed for the low-carbon hydrogen market – legally separating production, networks and distribution – might not match with the requirements for companies in the initial stages of market development.

6. Literature

BP (2022). bp Statistical Review of World Energy 2022 | 71st edition. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf

Cepsa (2022, October 11). Cepsa and the Port of Rotterdam join up to create the first green hydrogen corridor between the North and South of Europe, available at: https://www.cepsa.com/en/press/first-green-hydrogen-corridor. Last accessed on 26.03.2023.

Clean Energy Ministerial, Hydrogen, available at: https://www.cleanenergyministerial.org/initiatives-campaigns/hydrogen-initiative/. Last accessed on 23.11.2022

Clingendael International Energy Programme (2019). From an invisible to a more visible hand? Hydrogen and electricity: towards a new energy system backbone. Available at: https://www.clingendaelenergy.com/inc/upload/files/CIEP_Paper_2019_2B_web.pdf.

Clingendael International Energy Programme (2021). Hydrogen in North-Western Europe, a vision towards 2030. Available at: https://www.clingendaelenergy.com/inc/upload/files/NW-Europe-Hydrogen-Final.pdf.

Clingendael International Energy Programme (2022). Managing future security of low-carbon hydrogen supply. Available at: https://www.clingendaelenergy.com/inc/upload/files/CIEP-Paper-202201-web-2.pdf.

Correljé, A., Van der Linde, C., & Westerwoudt, T. (2003). Natural gas in the Netherlands. From cooperation to competition?. Available at: https://www.clingendaelenergy.com/inc/upload/files/Book_Natural_Gas_in_the_Netherlands.pdf.

D66 & VVD (2022). Nederland als waterstofkoploper - actieplan VVD-D66. Available at: https://d66.nl/wp-content/uploads/2022/04/Nederland-als-waterstofkoploper-actieplan-VVD-D66.pdf.

European Commission (2022), State Aid: Commission approves up to 5.4 billion euro of public support by fifteen Member States for an Important Project of Common European Interest in the hydrogen technology value chain, available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4544 Last accessed on 23.11.2022

European Hydrogen Backbone, Country Narratives, available at: https://ehb.eu/page/country-specific-developments Last accessed on 22.11.2022

European Parliament (2021). Revision of the Renewable Energy Directive: Fit for 55 package. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698781/EPRS_BRI(2021)698781_EN.pdf.

Government of the Netherlands (2016). Policy Document on the North Sea 2016-2021. Available at: https://www.government.nl/binaries/government/documenten/policy-notes/2015/12/15/policy-document-on-the-north-sea-2016-2021/nz-eng-beeldscherm.pdf.

Government of the Netherlands (2019). Klimaatakkoord. Available at: https://www.klimaatakkoord.nl/binaries/klimaatakkoord/documenten/publicaties/2019/06/28/klimaatakkoord/klimaatakkoord.pdf.

Government of the Netherlands (2022a), Gaskraan Groningen op waakvlam, available at: https://www.rijksoverheid.nl/actueel/nieuws/2022/09/26/gaskraan-groningen-op-waakvlam. Last accessed on 22.11.2022

Government of the Netherlands (2022b), Kabinet trekt extra 1,3 miljard uit voor waterstofprojecten, available at: https://www.rijksoverheid.nl/actueel/nieuws/2022/07/15/kabinet-trekt-extra-13-miljard-uit-voor-waterstofprojecten. Last accessed on 23.11.2022

Government of the Netherlands, Afbouw gaswinning Groningen, available at: https://www.rijksoverheid.nl/onderwerpen/gaswinning-in-groningen/afbouw-gaswinning-groningen#:~:text=Afbouw%20gaswinning%20naar%20nul&text=Vanaf%20oktober%202022%20staat%20het,winter%20of%20bij%20grote%20leveringsproblemen. Last accessed on 22.11.2022

Hydrogen Europe, EU projects - Hydrogen Europe, available at: https://hydrogeneurope.eu/eu-projects/. Last accessed on 23.11.2022

HyXchange, About us, available at: https://hyxchange.nl/about/. Last accessed on 13.12.2022

HY3, Decarbonizing the Dutch & German Industry through hydrogen, available at: https://hy3.eu/. Last accessed on 23.11.2022

H-vision, Using hydrogen to make large and fast cuts in carbon emissions, available at: https://www.h-vision.nl/en. Last accessed on 22.11.2022

Innovation Origins (2021), Germany is fully committed to hydrogen, and the Netherlands should follow suit, available at: https://innovationorigins.com/en/germany-is-fully-committed-to-hydrogen-and-the-netherlands-should-follow-suit/. Last accessed on 23.11.2022

IRENA (2022). Geopolitics of the Energy Transformation: The Hydrogen Factor. Available at: https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen.

Meijer, Bart (2022). Dutch court carbon capture project ruling alarms building sector. – Reuter, 2 November 2022, available at: https://www.reuters.com/world/europe/dutch-court-says-permits-major-carbon-storage-project-are-uncertain-2022-11-02/. Last accessed on 22.11.2022

MIEK (2021). MIEK overview 2021 Multiyear programme Infrastructure Energy and Climate. Available at: https://www.rijksoverheid.nl/documenten/rapporten/2021/11/26/meerjarenprogramma-infrastructuur-energie-en-klimaat---overzicht-2021. Last accessed on 08.12.2022

Ministry of Economic Affairs and Climate (2020). Government Strategy on Hydrogen. Available at: https://www.government.nl/documents/publications/2020/04/06/government-strategy-on-hydrogen.

Ministry of Economic Affairs and Climate (2022a). Kamer brief over garantieregeling Porthos. Available at: https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/documenten/kamerstukken/2022/12/09/garantieregeling-porthos.

Ministry of Economic Affairs and Climate (2022b). Kamerbrief over ontwikkeling transportnet voor waterstof. Available at: https://open.overheid.nl/repository/ronl-5c57a9ba35fa907dcc805ca0da463dc33b036bb8/1/pdf/ontwikkeling-transportnet-voor-waterstof.pdf.

Ministry of Economic Affairs and Climate (2022c). Kamerbrief voortgang ordening en ontwikkeling waterstofmarkt. Available at: https://open.overheid.nl/repository/ronl-c369632dae73cb4ed9dd9e8e4af10e64e74ae1f9/1/pdf/voortgang-ordening-en-ontwikkeling-waterstofmarkt.pdf.

Ministry of Economic Affairs and Climate (2022d). Nederlandse reactie op de publieke internetconsulatie door de Europese Commissie. Available at: https://open.overheid.nl/repository/ronl-1c27dc1e0ab3ace66554a763d09eadb2c70d0362/1/pdf/22229490bijlage-3-nederlandse-reactie-op-europese-consultatie-gedelegeerde-handelingen-hernieuwbare-waterstof.pdf

Mission Innovation, Catalysing clean energy solutions for all, available at: http://mission-innovation.net/. Last accessed on 23.11.2022

National Hydrogen Programme (2022). Routekaart. Available at: https://nationaalwaterstofprogramma.nl/documenten/handlerdownloadfiles.ashx?idnv=2339011.

National Hydrogen Programme (a), Import en export, available at: https://nationaalwaterstofprogramma.nl/themas/thema+import+en+export/default.aspx. Last accessed on 11.10.2022

National Hydrogen Programme (b), Subsidiemogelijkheden waterstof, available at: https://nationaalwaterstofprogramma.nl/kennisbank/2244223.aspx?t=Subsidiemogelijkheden-waterstof. Last accessed on 23.11.2022

National Hydrogen Programme (c), Thema's, available at: https://nationaalwaterstofprogramma.nl/themas/default.aspx. Last accessed on 20.10.2022

National Hydrogen Programme (d), Waterstofprojecten, available at: https://nationaalwaterstofprogramma.nl/kennisbank/2215926.aspx?t=Waterstofprojecten. Last accessed on 20.10.2022

Netherlands Enterprise Agency (2021a). Excelling in Hydrogen. Available at: https://www.rvo.nl/sites/default/files/2021/03/Dutch solutions for a hydrogen economy.pdf.

Netherlands Enterprise Agency (2021b). Programma Energyhoofdstructuur. Available at: https://www.rvo.nl/sites/default/files/2021/04/Concept-Notitie-Reikwijdte-en-Detailniveau-Programma-Energiehoofdstructuur.pdf.

Netherlands Enterprise Agency (2021c), Stimulering Duurzame Energieproductie en Klimaattransitie (SDE++), available at: https://www.rvo.nl/subsidies-financiering/sde?gclid=Cj0KCQjwxveXBhDDARIsAI0Q0x2yDvlyPafxqRxTifQs8-BsbzICfJ3zU-cydvQk8IGC5Yxu00Pr45MaAsEAEALw_wcB. Last accessed on 23.11.2022

NortH2, Kickstarting the green hydrogen economy, available at: https://www.north2.eu/en/. Last accessed on 23.11.2022

Pentalateral Energy Forum (2020). Joint political declaration of the pentalateral energy forum on the role of hydrogen to decarbonise the energy system in Europe. Available at: https://zoek.officielebekendmakingen.nl/blg-939618.pdf.

Port of Rotterdam (2022a), Broad industry support for Delta Corridor project, available at: https://www.portofrotterdam.com/en/news-and-press-releases/broad-industry-support-for-delta-corridor-project. Last accessed on 23.11.2022

Port of Rotterdam (2022b), Renewable liquid hydrogen supply chain between Portugal and Netherlands on the horizon, available at: https://www.portofrotterdam.com/en/news-and-press-releases/renewable-liquid-hydrogen-supply-chain-between-portugal-and-netherlands-on. Last accessed on: 13.12.2022

Port of Rotterdam (a), Import of hydrogen, available at: https://www.portofrotterdam.com/en/port-future/energy-transition/ongoing-projects/hydrogen-rotterdam/import-of-hydrogen. Last accessed on 22.11.2022

Port of Rotterdam (b), Refining and Chemicals, available at: https://www.portofrotterdam.com/en/setting/industry-port/refining-and-chemicals. Last accessed on 22.11.2022

Programme sustainability industry, Industrieclusters, available at: https://www.verduurzamingindustrie.nl/industrieclustersre/industrieclusters/default.aspx. Last accessed on 22.11.2022

Raad van State (2022), Bouw vrijstelling stikstof van tafel, maar geen algehele bouw stop, available at: https://www.raadvanstate.nl/actueel/nieuws/@133608/bouwvrijstelling-stikstof-van-tafel/ -highlight=porthos. Last accessed on 18.11.2022

RVO (2021). Excelling in hydrogen. Available at: https://www.rvo.nl/sites/default/files/2021/03/Dutch solutions for a hydrogen economy.pdf.

RWE, H2opZee, available at: https://www.rwe.com/en/research-and-development/hydrogen-projects/h2opzee. Last accessed 23.11.2022

Schaps, Karolin (2022). Dutch government to join German hydrogen import scheme. – Hydrogen Economist, 13 October 2022, available at: https://pemedianetwork.com/hydrogen-economist/articles/strategies-trends/2022/dutch-government-to-join-german-hydrogen-import-scheme/

Shell (2022), Shell start bouw van Europa's grootste groene waterstoffabriek in Rotterdam, available at: https://www.shell.nl/media/nieuwsberichten/2022/holland-hydrogen-1.html. Last accessed on 16.10.2022

Tata Steel (2021), Klimaatambities, available at: https://www.tatasteeljobs.nl/nieuwsberichten/2021/klimaatambities.html. Last accessed on 20.10.2022

TNO (2020). The Dutch hydrogen balance, and the current and future representation of hydrogen in the energy statistics. Available at: https://repository.tno.nl/islandora/object/uuid%3A77b361fb-0598-40aa-8be2-97e1f6e73ce5.

Topsector Energy (2020). Overview of Hydrogen Projects in the Netherlands. Available at:

https://www.topsectorenergie.nl/sites/default/files/uploads/TKI Gas/publicaties/Overview Hydrogen projects in the Netherlands versie 1mei2020.pdf.

Topsector Energy (2022), Geld uit het Nationaal Groeifonds voor innovatie waterstof en duurzame materialen, available at: https://www.topsectorenergie.nl/nieuws/geld-uit-het-nationaal-groeifonds-voor-innovatie-waterstof-en-duurzame-materialen. Last accessed on 23.11.2022

van der Linde, C., Stapersma, P. (2018). The Dutch energy economy: the energy gateway to Northwest Europe. Available at: https://spectator.clingendael.org/pub/2018/2/the-dutch-energy-economy/.

7. About the authors

Roelof Stam
Researcher, Clingendael International Energy Programme (CIEP)

Coby van der Linde
Director, Clingendael International Energy Programme (CIEP)

Pier Stapersma
Senior Researcher, Clingendael International Energy Programme (CIEP)

The **Research Institute for Sustainability (RIFS)** conducts research with the aim of investigating, identifying, and advancing development pathways for transformation processes towards sustainability in Germany and abroad. The institute was founded in 2009 as the Institute for Advanced Sustainability Studies (IASS) and has been affiliated with the Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences under its new name since 1 January 2023 and is thus part of the Helmholtz Association. Its research approach is transdisciplinary, transformative, and co-creative. The Institute cooperates with partners in science, political and administrative institutions, the business community, and civil society to develop solutions for sustainability challenges that enjoy broad public support. Its central research topics include the energy transition, climate change and socio-technical transformations, as well as sustainable governance and participation. A strong network of national and international partners and a Fellow Programme supports the work of the Institute.

RIFS Discussion Paper

April 2023

Contact:
CIEP: ciep@clingendaelenergy.com

Address:
Berliner Strasse 130
14467 Potsdam
Tel: +49 (0) 331-28822-340
Fax: +49 (0) 331-28822-310
Email: media@rifs-potsdam.de
www.rifs-potsdam.de

ViSdP:
Prof. Dr Mark G. Lawrence,
Scientific Director, Speaker

DOI: 10.48481/rifs.2023.013