Green Hydrogen State of the Nation Report

The Netherlands

A report highlighting the Status and Development of the Green Hydrogen Sector in the clusters of Belgium, the UK, Germany, and the Netherlands.

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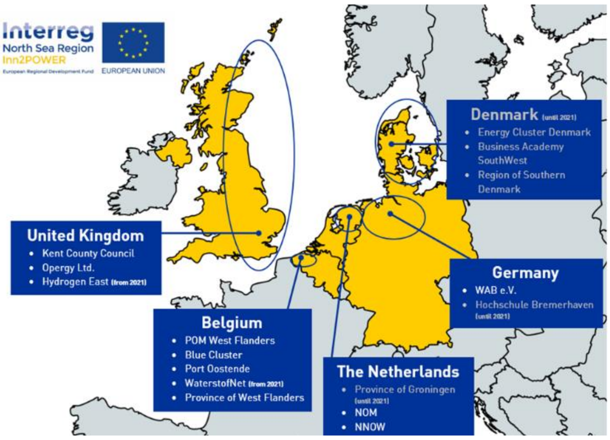
1. Introduction

About Inn2POWER



This Inn2POWER project brings together the forces of nine partners in four countries in the North Sea region (NSR): the UK, Belgium, the Netherlands, and Germany. The aim is to expand the capacity for innovation and improve access to the offshore wind industry and green hydrogen for SMEs through connecting offshore wind and green hydrogen businesses in the NSR.

The overriding vision of Inn2POWER is to strengthen the North Sea Regions through supporting SMEs to collaborate and enter new markets through Inn2POWER's company directly, focusing on offshore wind and green hydrogen; grant easy access to test and demonstration facilities; and to improve knowledge, skills and availability of qualified staff.

2. Defining Green Hydrogen

Hydrogen is not an independent energy vector; it is always paired with or dependant on another technology to produce the power for hydrogen production. For this report, and the Inn2POWER project, we will focus on the developing 'Green Hydrogen' Sector across the North Sea Region (NSR). This chapter defines what is meant by this definition.

The Rainbow of Hydrogen Production

The source of power used to drive the process of Hydrogen Production is commonly referred to as colours. The term 'Green Hydrogen' has become commonly used to describe Hydrogen Production powered by low-carbon and renewable sources of power. The following table summarises the general definitions of Green Hydrogen as compared to other types of Hydrogen Production.

Colour	Process	Impact
Green Hydrogen	Electrolysis, using renewable energy (wind, solar etc.) to split water into its component parts (H_2 + O_2).	No carbon emissions, ability to "store" surplus electricity from renewable sources.+
Yellow Hydrogen	As above, using nuclear power instead of renewable energy.	Low carbon emissions, ability to "store" surplus electricity.
Brown Hydrogen	Gasification, using coal/biomass/waste to heat water and break it down. Also known as "town gas".	Along with the component parts of water, other harmful elements are produced: carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and ethylene (C_2H_4).
Grey Hydrogen	Steam Methane Reforming (SMR), using methane to heat water and break it down.	As above, produces other harmful elements: CH_4 and CO_2.
Blue Hydrogen	SMR and carbon capture, use and storage (CCUS).	Grey hydrogen but with carbon 'capture so it is seen as a lower carbon option.
Turquoise Hydrogen	Using Molten Metal Pyrolysis, natural gas is passed through a molten metal that releases hydrogen and solid carbon.	Solid carbon can be used for industrial applications, so it is seen as a lower carbon option.

Defining Green Hydrogen Across the NSR

More specifically, Green Hydrogen has been defined at the European level in the EU's Hydrogen Strategy; A case for urgent action towards implementation published in July 2020. This defines green hydrogen as follows:

"*hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources. The full life-cycle greenhouse gas emissions of the production of renewable hydrogen are close to zero. Renewable hydrogen may also be produced through the reforming of biogas (instead of natural gas) or biochemical conversion of biomass, if in compliance with sustainability requirements".*

Across the other countries in Europe, definitions are outlined across strategy and policy documents published by each nation.

UK - UK Hydrogen Strategy (publishing.service.gov.uk)
DEFINITION: Hydrogen which is produced through electrolysis, where electricity is used to split water into hydrogen and oxygen – gas from this process is often referred to as 'green hydrogen' or zero carbon hydrogen when the electricity comes from renewable sources.

For the purposes of the UK definition, hydrogen production via nuclear powered electrolysis is considered within the scope of Green Hydrogen.

Germany - Nationales Reformprogramm 2020 (bmwi.de)
DEFINITION: The Federal Government considers only hydrogen that has been produced using renewable energy (green hydrogen) to be sustainable in the long term. The Federal Government therefore seeks to use green hydrogen, promote its rapid market rollout and establish the necessary value chains.

The Netherlands & Belgium seemingly use the EU definitions with hydrogen papers published by Netherlands government (Government Strategy on Hydrogen | Publication | Government.nl) about the existing state of the nation and market for hydrogen (transport, electricity, agriculture, buildings).

3. The Green Hydrogen Policy Landscape

National Policy Landscape

In 2019, the Dutch government introduced the Klimaatakkoord (climate accord), with an ambitious goal. A 49 to 55% reduction of greenhouse gases in 2030, compared to 1990. This accord states that a combination of sustainable energy and CO2 neutral energy carriers – mainly hydrogen- is essential in accomplishing this goal. Widespread use of hydrogen will reduce yearly greenhouse gases with 5,5 to 11 Mt – 2,5 to 5% of the 1990's emission levels.

The climate accord has garnered broad public support as well as support from highly respected organizations throughout the Netherlands, 50 of which have signed the accord. Following from this is the Kabinetsvisie Waterstof (Cabinet's Vision on Hydrogen). This document states in more detail how hydrogen can contribute to the decarbonization of economic sectors that have proved difficult to move away from fossil fuels.

In the energy transition of the Netherlands, blue and green hydrogen play a key role in achieving these climate goals. Hydrogen enables sectors that are traditionally difficult to reduce emissions (such as industrial , industrial heating, heavy transport and marine appliances) to decarbonize. With this, the energy sector can also exploit a fully carbon-free energy system that allows for flexibility in terms of large-scale wind and solar energy integration, enables for long-term energy storage for periods of peak demand. Additionally, the economy of the Netherlands can achieve a competitive edge by making the transition early, leading to improved air quality and the reduction of other polluting chemicals, like nitrous oxide and particulate matter.

Finally, widespread hydrogen adoption enables the Netherlands to leave behind the natural gas economy while still being able to profit of existing knowledge and infrastructure. As a consequence of the earthquakes caused by the extraction of the Groningen gas field, the Netherlands has indicated not wanting to be the leading European natural gas provider in the future. This leads to a potential of 20.000 jobs in the gas industry that will become obsolete. Due to the similarities between hydrogen and natural gas however, the switch to hydrogen can be seen as a prolongation of the existing gas knowledge, infrastructure and trade experience, while aiming for the economic benefits of the predicted increase of demand for hydrogen.

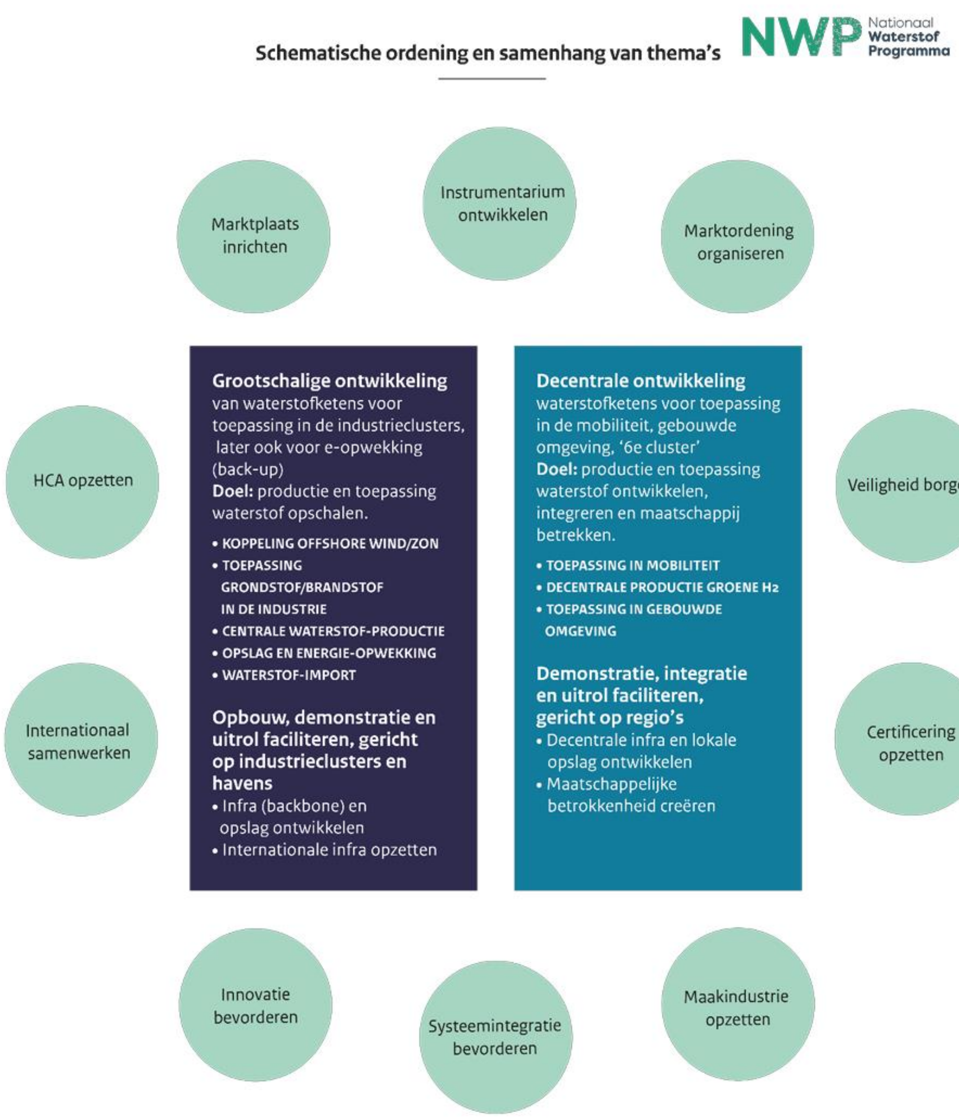
National Hydrogen Program

To implementate the climate accord, the government wrote the Nationaal Waterstof Programma (National Hydrogen Program). The program describes the implementation of the hydrogen plans for 2022 – 2025.

The goals is to connect the national and local development. The intention in the NWP is thatall lines related to the development of hydrogen come together, in such a way that relationships with all kinds of developments and activities can be executed.

A conceptual approach is proposed for the implementation of the work plan with clear tracks

1. **The large-scale development of hydrogen in industrial clusters and ports.** This track is about the rapid upscaling of the offshore production of sustainable electricity from wind and possibly solar in the future, coupled with the upscaling of electrolysis for green hydrogen, which can be used in the five industry clusters, in heavy transport and logistics, in the ports for the sustainability of raw materials and fuels and in CO2-free, controllable power stations as a back-up for variable sustainable generation.
2. **Decentralized development of hydrogen in the regions**. This track is about the demonstration and expansion of hydrogen production at a decentralized level. Local generation of sustainable energy like solar and wind can be linked to the backbone. This solution makes the application of hydrogen in regional projects such as heavy transport and mobility, the sixth industry cluster , the agricultural sector and the built environment, where local grid congestion problems can also be reduced that hinder the further development of sustainable energy projects.
3. **To enable large-scale and decentralized track, the right preconditions must be created that lay the foundation for the development of hydrogen.** This means policy, legislation and regulations, market organization, safety, social embedding, certification, development and organization of the manufacturing industry, innovation, human capital**.**



Figuur 3. Schematische ordening en samenhang van thema's in het NWP

Regional / Cluster Policy Landscape

The Northern Netherlands is acknowledged as the leading hydrogen valley in Europe. Building upon the current momentum, acknowledgement and level of ambition, the region would like to retain this position after 2030 and wants to encompass the entire hydrogen value chain.

1. Access to the European markets for hydrogen with a predicted 400PJ/y (petajoule) requirement in 2030.
2. A large offshore wind potential, located north of the Northern Netherlands, with space for more than 20GW, with 4-6 GW being allocated for the production of green hydrogen.
3. Strategic location for the production of hydrogen in industrial hubs (Delfzijl, Eemshaven, Emmen) to create a production capacity of 100PJ/y in 2030.
4. Expansive and available gas infrastructure; including parallel gas pipe lines, salt caverns for storage and strategically located seaports.
5. Knowledge about trade, transport and innovation in both the traditional natural gas industry as well as the hydrogen industry, built upon the position of the Netherlands position as the European leader in terms of

In order to realize the ambitions of the Northern Netherlands in a systematic way, a roadmap with two phases is implemented:

- Phase 1: Development and scale-up (2020 – 2025) From now until 2025, the Northern Netherlands will develop between 5 – 10 PJ capacity per year, and scale up the value chain from production and infrastructure to use-cases. In order to realize this, approximately 850 million euro is required. Besides these private investments, additional political and financial commitments are necessary to guarantee this timeline.
- Phase 2: Expansion to North-Western Europe (2025 – 2030) Starting from 2025, the hydrogen ecosystem capacity in the Northern Netherlands will grow with 100PJ per year. 75% of this will be green hydrogen (6GW), the remaining 25% will be blue hydrogen. The region will increase its demand to supply the hydrogen markets of North-Western Europe with 400PJ per year. Large projects stimulate the integration of hydrogen ecosystems, while domestic and international infrastructure will connect the Northern Netherlands to the North-West European markets. In order to realize these projects, more than 9 billion will be invested. Additionally, governmental action is required in the short term to stimulate the use of hydrogen, increase offshore wind capacity, and to synchronize boundary crossing investments as well as legislation.

European Hydrogens Hub – H2 Proposition Port of Rotterdam

Rotterdam has the industry, knowledge institutes and transportation capabilities to be the European Hydrogen Hub, and supply Europe's hydrogen demands. In triple helix collaboration, this region works towards international climate goals.

Rotterdam is the energy port of Northwest Europe, where 8,800 petajoules PJ) of energy is supplied and removed by seagoing vessels every year, almost three times as much as the energy demand in the Netherlands, and 13% of the energy demand in the EU.

Most of this energy now comes from fossil fuels. In a world with climate-neutral energy systems in 2050, the ambition of the Port of Rotterdam is be an import hydrogen hub for North Western Europe. Every year 20 million tons (mt) of hydrogen (2400pj) will pass. This requires more than 100 gigawatts (GW) of electrolysis capacity, and double the power for electricity production due to the non-continuous supply of sun and wind.

Dutch offshore wind will be able to contribute to this for a small part in 2050, but the largest part will be imported from areas where renewable electricity is much cheaper and where it already is converted into hydrogen. Due to converting, hydrogen will be more easy to transport. A large part will find its way through the hydrogen backbone to Europe for use in industry and transport.

Local production

Several companies are working on concrete projects aimed at launching large-scale production of electrolytic hydrogen powered by North Sea wind power between 2024 and 2026.
Together, all of the projects and plans would be good for 2.5 GW of electrolysis by 2030 and produce 0.25 Mt of green hydrogen. A project to produce low-carbon hydrogen from refinery gas is also underway. This would mean a total of 0.6 Mt of hydrogen could be produced locally by 2030.

Imports

Importing energy will remain necessary. Europe does not have the capacity to produce enough renewable energy to meet the 2030 and 2050 targets. The sooner Europe starts replacing imports of oil, gas and coal with imports of green and low carbon energy, the sooner it will achieve the European climate and energy independence objectives. Green hydrogen can be produced wherever there is abundant supply of sun, wind and space. From Southern Europe and North Africa to Australia and Latin America. Diversity of supply, is security of supply. Our first import projects (hydrogen and its derivatives) add up to at least 4 Mt in 2030.

Infrastructure

Supplying end-users in NW Europe with large volumes of hydrogen affordably, safely and reliably from ports such as Rotterdam will require a pipeline infrastructure. This will begin as an infrastructure within coastal industrial clusters, and between ports and inland industrial clusters, allowing us to transport hydrogen from Rotterdam to steel, chemical, cement and industries at large as well as to filling stations to fuel trucks and barges

Rotterdam sees himself as the European Hydrogen Hub for import and export of hydrogen.

Smart Delta Region

The Smart Delta Region represents a Dutch-Belgium crossboarder industrial cluster focused on the implementation of large-scale green (and blue) hydrogen as a feedstock material in the chemical, refinery and steelmaking industry.

The companies that have been working closely together in SDR (Smart Delta Region) since 2014 have developed the ambitious Hydrogen Delta program for further synergy.

The main landing point for wind farms in the North Sea is located in the SDR region, creating potential ground for green hydrogen production.

Targets are:

1. Hydrogen kickstart locations (100 – 200MW) in the port by 2025.
2. Connecting to the national backbone by 2028
3. Developed a local hydrogen infrastructure in the port by 2030
4. North Sea Port has been further developed as a strategic hydrogen hub for import, storage and export in 2050.

Hydrogen Delta focusses on the hydrogen requirements of the five industrial clusters.

4. The Green Hydrogen Development Pipeline

National Development Pipeline

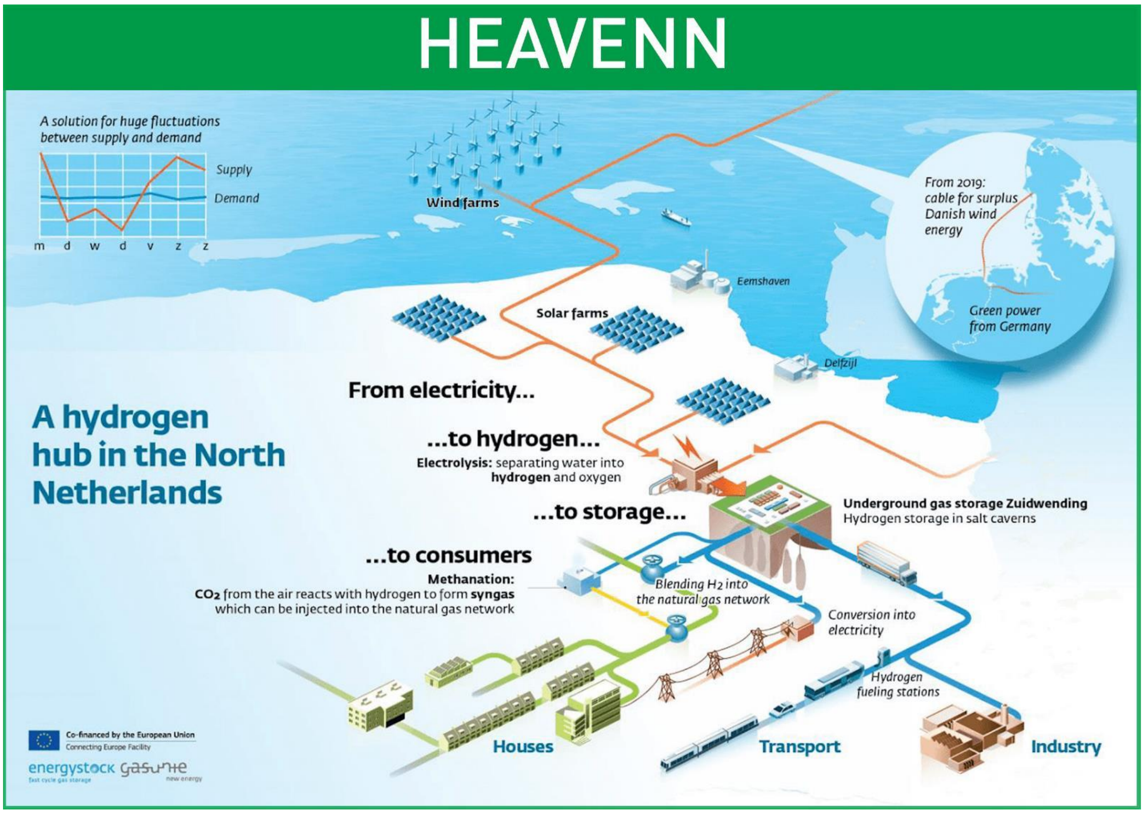
- **PosHYdon,** which will be hosted on the Neptune Energy-operated Q13a-A platform, aims to validate the integration of offshore wind, offshore gas and offshore hydrogen in the Dutch North Sea. It will see the installation of a green hydrogen-producing plant on Neptune Energy's Q13a-A platform. The plant will convert seawater into demineralised water, then into green hydrogen via electrolysis, which will be blended with natural gas and transported to shore via an existing pipeline
- **H2Gate** focuses on the development of large-scale hydrogen imports to the Amsterdam port region (1 million ton per year). The project focuses on several hydrogen carriers that match the infrastructure in the port. The expected result of the first step is a blueprint that reveals the potential and challenges for large-scale green hydrogen import, and a roadmap that identifies concrete next steps for the development of a demonstration project. The first phase of the project will run to July 2021. The aim for the realization of the import terminal is around 2030.
- **ELYgator**, a large-scale 200MW water electrolyser project that will be entirely sourced from renewable power sources and will enable avoidance of 4M tons of CO_2 over the first 10 years of the plant's operation. The unit is planned to become operational in 2024 and produce over 18 ktons of renewable hydrogen per year which will be injected into Air Liquide's European cross-border hydrogen network and dedicated to both mobility applications as well as industrial applications.
- **H^2ero**: The project initially consists of a feasibility study into a 150 MW electrolyser on the site of Zeeland Refinery in Vlissingen. This location is particularly suitable given its location in an already highly hydrogen-intensive region with many opportunities for setting up and scaling up a 'low-carbon' hydrogen value chain. An annual production of 23 kT of green hydrogen can be expected with the installation, which is equivalent to an avoided CO_2-emission of approximately 200 kTa compared to H_2 production through the conventional fossil route
- **GreenH2UB** is a 5-10 MW green hydrogen plant based on PEM electrolysis. Application and deployment in industry, mobility and built environment. The realization of the first GreenH2UB is set for the KBP in the Metropol Region Eindhoven. The GreenH2UB will be connected directly to wind farm de Pals and solar farms. Finished the Concept Design and obtained a positive Feasibility Study.

Transportation:

Gasunie is building a national network that will connect future carbon-free hydrogen supply and demand. Five industrial clusters will be linked to each other, to foreign countries and to hydrogen storage facilities. This will be done mainly with existing natural gas infrastructure and partly with new infrastructure that has yet to be built. Current plans call for the first parts of the national backbone to be available in 2025. These are located in the north of the Netherlands, and in the Rotterdam area

Regional / Cluster Development Pipeline

- **HEAVENN:** a six-year European program in which more than thirty public and private parties are contributing to the creation of Hydrogen Valley, an ambitious and comprehensive hydrogen network in the Northern Netherlands.



- **Hystock:** An electrolyser that converts solar energy into hydrogen, which subsequently stores this gas in salt caverns. The caverns function as a lung in the hydrogen network and enable the entire energy system in the Netherlands and Europe to achieve ambitious sustainability targets.

- **HyNetherlands:** Currently ENGIE & Gasunie are working together on the construction of a 100MW electrolyser. This is around a 100 times larger than Gasunie's Hystock electrolyser, currently the largest electrolyser that operates with green energy. HyNetherlands is meant to scale up to the gigawatt scale in the future.

- **NorthH2:** a consortium of Shell, RWE, Groningen Seaports, Equinor & Gasunie set on large-scale green hydrogen production using offshore wind power. Their goal is to produce 4 gigawatts by 2030, and upscaling to more than 10 gigawatts by 2040.

- **Djewels 1&2:** Djewels is a project that aims to demonstrate the operational readiness of a 20 MW electrolyser for the production of green fuels (green methanol) in real-life industrial and commercial conditions.

- **Hydrohub MegaWatt Test Centre** tests new hydrogen developments on a larger scale, identifying potential new problems and how the technology will behave when it is scaled up. Once the hydrogen technology has been adequately tested in the Hydrohub, it can be incorporated straight away into an electrolysis installation on an industrial, gigawatt scale
- **Eemshydrogen:** RWE plans to build an electrolyser for the production of hydrogen on the Eemshaven power plant site. The unit has projected capacity of

50 megawatts and will be connected directly to RWE's Westereems wind farm, one of the largest onshore wind farms in the Netherlands. The renewable power generated by the wind farm will be used to produce green hydrogen.

- **RelyOnNutec**: is currently constructing an educational center in the Eemshaven that provides training for employees both active in the offshore wind sector, as well as the future hydrogen sector.

Pipeline for Electrolyser projects in the Northern Netherlands:

	Company Name	Project	Location	Capacity[1] PJ per annum	Capacity[1] MW	Date ready
Hydrogen production	Industry coalition	Battolyser pilot plant	Eemshaven	0,001	0,015	2019
	Lagerwey	H_2 windturbine	Eemshaven, Delfzijl	0,02	2-3	2020
	Lagerwey	4 H_2 windturbines	Eemshaven, Delfzijl	0,1	10	2020-22
	Shell, EBN, Gasunie	GZI Next Phase 1[2]	Emmen	0,1	10	2022
	Nouryon, Gasunie	DJEWELS 1	Delfzijl	0,4	20	2022
	Nouryon, Gasunie	DJEWELS 2	Delfzijl	1,7	80	2022
	Shell, EBN, Gasunie	GZI Next Phase 2[2]	Emmen	0,8	40	2023
	St. WadDuurzaam, St. Humsterland	Electrolyser including storage	Lauwersoog	0,025	1,5	2023-24
	RWE	Eemshydrogen	Eemshaven	0	100	2023-24
	Engie, Gasunie (infrastructure partner)	HyNetherlands Phase 1	Eemshaven	0,03	100	2024
	D4	Biomass and electrolysis hydrogen production	Leeuwarden	0,1	10	2024
	Shell, EBN, Gasunie	GZI Next Emmen scale-up[2]	Emmen	3,2	200	2026
	Equinor, Gasunie	H2M, blue hydrogen via ATR	Eemshaven	28	1.000	2027
	Nouryon	200MW electrolyser	Delfzijl	3,2	200	2027
	Gasunie, Shell, Groningen Seaports	NorthH_2 Phase 1	Eemshaven	10	1.000	2027
	Engie, Gasunie (infrastructure partner)	HyNetherlands Phase 2	Eemshaven	12,3	750	2028
	Engie, Gasunie (infrastructure partner)	HyNetherlands Phase 3	Eemshaven	16,4	1.000	2030
	Gasunie, Shell, Groningen Seaports	NorthH_2 Phase 2	Eemshaven	29	3.000	2030
	Gasunie, Shell, Groningen Seaports	NorthH_2 Phase 3	Eemshaven	58	>6.000	2040

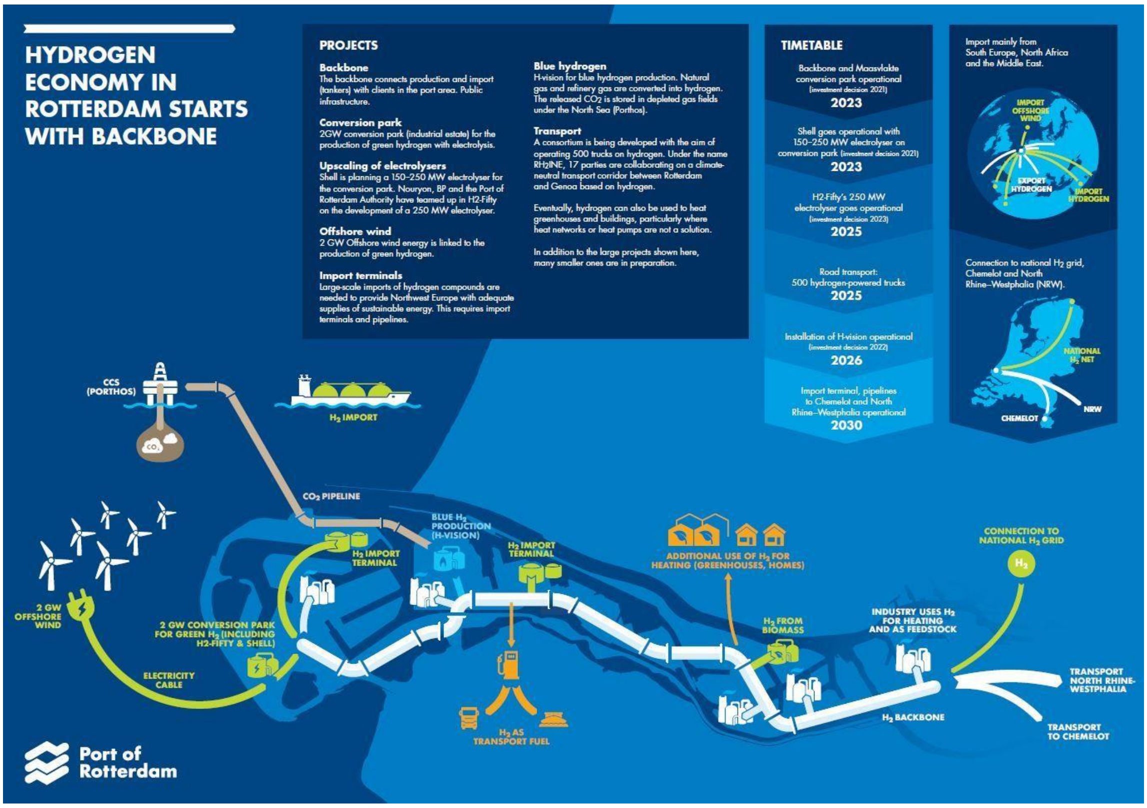
Note: these include all electrolyser plans, not only green hydrogen production. "Date ready" column might also be too optimistic for a few of these projects

Port of Rotterdam

H2-Fifty: Building a 250 MW Electrolysis Plant in Port of Rotterdam The new factory will be able to produce 45,000 tons of green hydrogen annually. Because the hydrogen is produced from water with sustainable electricity, CO_2 emissions can decrease by 350,000 tons annually. BP will use the green hydrogen to desulphurise products and mobility projects. The H2-Fifty project will be in the so-called Conversion Park, a special site that the Port Authority is building on the Maasvlakte for electrolysers from various companies. In 2025 the plan is to be operational.

H-Vision: Eleven major parties from the port industrial area of Rotterdam have joined forces with a number of knowledge partners to develop an innovative solution with which they can quickly reduce large amounts of CO2. Air Liquide, BP, Deltalinqs, EBN, Equinor, ExxonMobil, Gasunie, Port of Rotterdam Authority, ONYX Power, Shell, and Royal Vopak together represent the entire hydrogen chain, from production to end use. The partners bring together supply and demand for low-carbon hydrogen by developing them simultaneously. H-vision provides for the construction of two hydrogen plants:

Plant 1 in 2027 – 750 megawatts of low carbon hydrogen
Plant 2 in 2032 – 1.500 megawatts of low carbon hydrogen

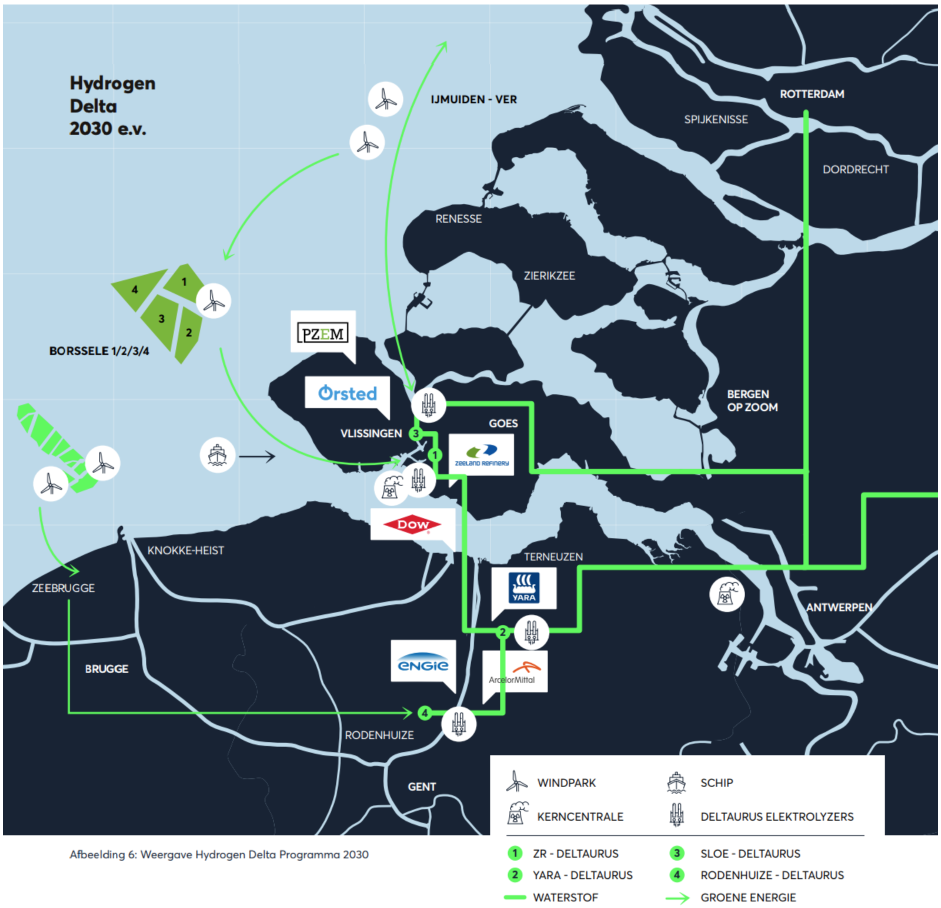


Smart Delta Regio

In the Delta region you have one particular project what is connected to the backbone:

- Deltaurus 1: kick-start production Zeeland Refinery 150 MW in ~ 2024, growth path to 1 GW in 2030;
- Deltaurus 2: kick-start production Yara Sluiskil 100 MW in ~ 2025, growth path hydrogen supply via pipeline infrastructure or additional electrolyser production in the event of a connection to the 380 kV grid;
- Deltaurus 3: central production location Sloe (Thermphos and/or Zanddepot) 700 MW in ~ 2027, growth path to multiple GW scale in 2030-2040 in connection with national hydrogen backbone (with storage facilities in salt caverns);

- Deltaurus 4: central production location Rodenhuize (Flanders) 60 MW in ~ 2025 growing to 600 MW in 2030, in connection with national hydrogen backbone (with storage facilities in salt caverns)



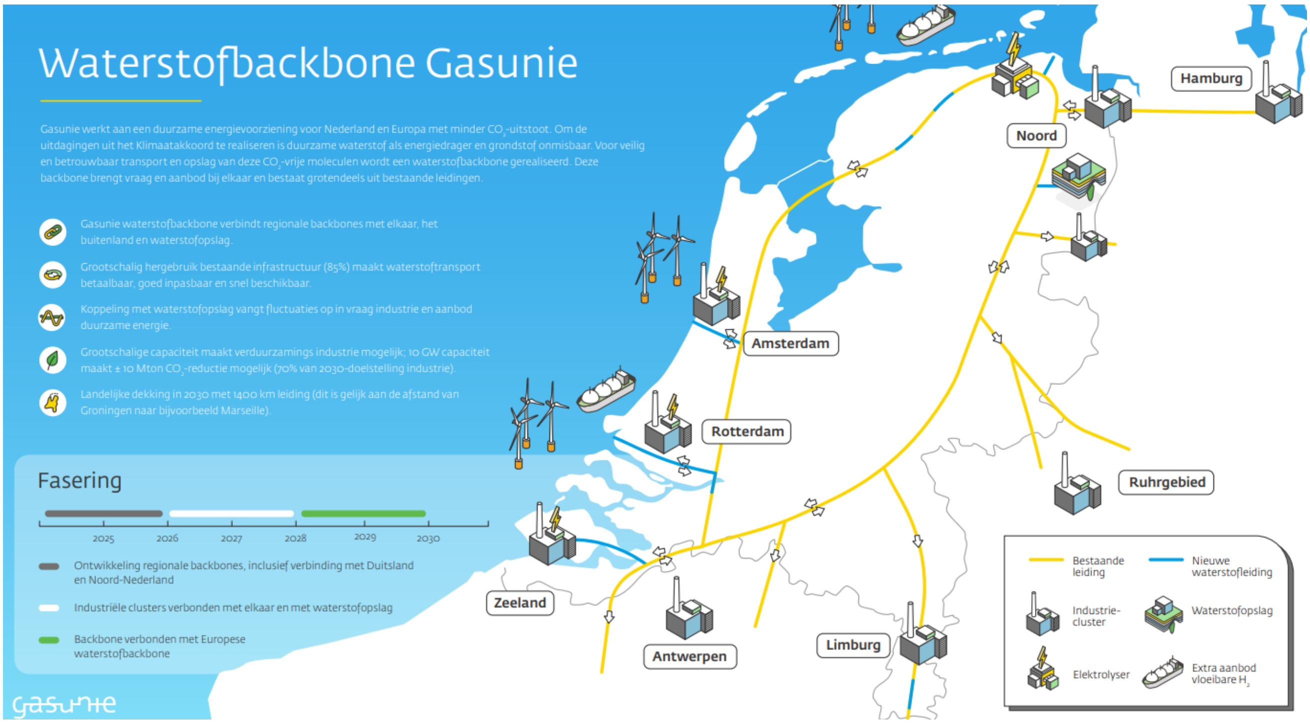
Afbeelding 6: Weergave Hydrogen Delta Programma 2030

5. Developing a Hydrogen Network

HyNorth:
HyNorth is all about the North as a frontrunner of the hydrogen economy. We are there for companies, knowledge institutions, governments and other hydrogen stakeholders in the Northern Netherlands. The challenges faced by an individual business are complex and time-consuming. HyNorth will be responding to this by acting as the supply chain director, supported by the regional business community, governments, and knowledge institutes, to develop hydrogen chains in the Northern Netherlands.

Gasunie*:*

Current plans call for the first parts of the national backbone to be available in 2025. These are located in the northern part of the Netherlands, and a link with northern Germany will already have been established by then. In addition, several industry clusters (in the IJmond and Rijnmond regions) are working together with local industrial players on regional hydrogen backbones. Around 2025, a start will be made on connecting the regional pipelines with each other, with foreign countries and with hydrogen storage facilities, so that they become part of the national and the future European hydrogen backbone. In the development of the backbone, existing natural gas pipelines will used for the most part. They will become available because there will be less and less transport of natural gas in the years to come. It is estimated that about 85% of the hydrogen backbone will consist of recycled natural gas pipelines. Gasunie will thus be contributing significantly to making the energy transition affordable.



Regional:

Port of Rotterdam

This HyTransPort.RTM pipeline integrates local production, import of large volumes of hydrogen from other parts of the world and transit to the hinterland. North Western Europe will have a significant demand for hydrogen in the future that can only be achieved through imports. The strategic role that Rotterdam now plays in the predominantly fossil fuel flows can soon also be taken up in the new energy system. This project is being developed by Gasunie and the Port of Rotterdam Authority. This will connect with the national backbone.

Hydrogen Delta Valley

Smart Delta Resources contributes to various studies, subsidy programs and projects within the Hydrogen Delta program, such as:

• Hydrogen Hub: feasibility, market potential and logistical implications of large-scale import/transshipment/export
• Electrolyser system integration
• Development of local hydrogen infrastructure in the Vlissingen-Terneuzen-Ghent port area with connections to national backbones (Gasunie, North Sea Port, Fluxys)
• Collaboration in initiatives to promote the hydrogen transition for industry
• Representation of the region in national and European working groups and hydrogen programmes
• Support subsidy processes for hydrogen projects

FME

Additional to the region network there is already a study which shows involving companies in the hydrogen supply chain. The study has been done by FME (entrepreneurs organisation for technical industry) and is as followed:

Alternatief	Systeem	Partijen
Toepassingsgebieden		
Industrie	Productie, conditionering	Air Liquide, Air Products, Linde, Nouryon
Gebouwde omgeving	CV-ketels	Remeha (BDR), Bekaert, ATAG
Transport mobiliteit	Personenauto's	n.v.t.
Transport mobiliteit	Tankstations	Pitpoint, Resato
Transport mobiliteit	Bussen	VDL, Ebusco
Transport mobiliteit	Vrachtwagens	DAF, ETrucks, GINAF, VDL
Transport mobiliteit	Bijzondere voertuigen	Spijkstaal, Terberg, Kenbri, Holthausen, Alstom
Transport mobiliteit	Binnenvaartschepen	VEKA
Elektriciteitsproductie	E-centrales	Nuon/Vattenfall, Engie
Elektriciteitsproductie	Aggregaten	Bredenoord
Distributie		
Distributie- pijplijn	Backbone	Gasunie (TSO)
Distributie- pijplijn	Distributienet	Netbeheerders (DSO)
Distributie- schip	Waterstoftankschip	Onbekend
Distributie- spoor	Waterstoftrein	Onbekend
Distributie- weg	Vrachtvervoer	Schenk, Jongeneel
Opslag en overslag		
Opslag en overslag- cavernes	Zoutcavernes incl. installaties	Energystock
Opslag en overslag- hogedruk	Tanks en compressoren	Vopak, Gasunie, Howden
Opslag en overslag- vloeibaar	Tanks en koelinstallaties	Vopak, Gasunie
Opslag en overslag- dragers	Omzettingsinstallaties	Onbekend
Productie		
Alkalische elektrolyse	Fabriek	Nouryon
Alkalische & PEM-elektrolyse	Demiwater/waterzuivering	Waterbedrijven (Bijvoorbeeld Evides)
PEM-elektrolyse	Fabriek	Siemens
Kleinschalige elektrolyse	Lokale installatie op E-net	Hydron, HyGear
Combinatie E-opwekking/waterstofproductie	Waterstofmolen	Hygro
Combinatie E-opwekking/waterstofproductie	Waterstofzonnepaneel	Onbekend (KU Leuven/Differ) TRL <6
Algemeen		
Onderzoek	Kennisinstelling	TNO/ECN, Differ
Opleiding en training	Universiteit	TU Delft, TU Eindhoven, TU Twente
Opleiding en training	Hbo	HAN, Haagse Hogeschool, Hanzehogeschool Groningen, Noorderpoort
Opleiding en training	Mbo	Noorderpoort
Opleiding en training	Beroepsopl./brandweer/politie	IFV, Falck, STC
Normering en testen		DNV GL, KIWA, Vincotte

Consulting with the Industry

Here you can read the organizations who has been involved to help to write this report.

Like mentioned before **HyNorth** is all about the North as frontrunner of the hydrogen economy. They will act like supply chain director to develop hydrogen chain in the Northern Netherlands.

New Energy Coalition is a continuously growing network of knowledge institutions, businesses, government bodies and ngo's working together to accelerate the energy transition for a sustainable future.

N.V. Nom investment and development agency for Northern Netherlands. They set up the NNOW (Northern Netherlands Offshore Wind). The aim of the Nom is to provide a cluster for acquisition, promotion and knowledge exchange.

TCNN has been involved by the NOM. TCNN is responsible for the project management of Inn2Power projects.

The province of Groningen provides investment program. Also one of the stakeholders who is in charge of the policy and for the performance of the hydrogen program.

Chemport Europe is a knowledge partner for gathering information how to use (green) hydrogen in industrial areas.

Groningen Seaports strongly advocates scaling up the production of green hydrogen. Groningen Seaports is fully committed to innovation and offers space and facilities for test centres, start-ups, scale-ups, pilot and demo plants.

Hydrogreenn provides a platform to inform people about hydrogen. This includes the lectures, project results/examples, student demonstrations and the increased hydrogen facilities and infrastructure in the demonstrationlab.

EnTranCe, the Centre of Expertise Energy, speeds up the transition to clean, renewable and affordable energy. EnTranCe is involved by different researches according the application of green hydrogen in the sustainable energy supply.

The Offshore Wind Innovation Centre (OWIC) in Eemshaven is an information, training and innovation centre aimed at companies and knowledge institutions involved in offshore wind energy. The aim of OWIC is to facilitate the development of activity and innovation in the field of offshore wind energy. It brings together knowledge and experience and makes it accessible to governments, knowledge institutions and the business community

6. Challenges and Opportunities of the Green Hydrogen Sector

Challenges for the Northern Netherlands

A) Hydrogen production, infrastructure & demand

1. **Establish supportive regulatory frameworks for production and demand**, and implementing measures to promote the use of hydrogen or hydrogen derivatives with end users.
2. **Introducing funds for scaling up hydrogen and supporting instruments** in order to alleviate the investment gap for the hydrogen ecosystem
3. **Compensating the initial investment gap for essential infrastructure** in order to create future-proof infrastructural investments that facilitate the creation of the hydrogen ecosystem
4. **Stimulating a grow of hydrogen demand** through supportive regulatory frameworks and a trade market for hydrogen

B) Offshore Wind Capacity

The capacity of offshore wind for the production of green hydrogen needs to be sped up in order to meet the planned 75 PJ in 2030. Current plans for 1,2 GW of offshore wind capacity close to the Northern Netherlands are not sufficient to reach this goal, and in 2030, more than 4 GW of additional capacity is necessary.

(C) The broader hydrogen ecosystem

1. **Invest in the needs for building up of the broader hydrogen ecosystem –** with the use of educational programs and supporting innovation centers in the region
2. **Transfer of intangible assets (talent, knowledge, innovation)** from other industries

D) Establishing overarching Program Management

1. Ensuring that the majority of the **European Just Transition Fund** is used for developing a hydrogen ecosystem in the Northern Netherlands
2. **The development of the hydrogen ecosystem** by setting up a transformation- and coordination office in the Northern Netherlands.
3. **Directing a systemic, national approach** for the end-to-end development of the hydrogen ecosystem. Regional and national governments must cooperate in order to ensure system wide direction.

7. Barriers and Opportunities for Innovation

The ambitions are great and focusses at the development of hydrogen chains in the period up to 2025. Via pilots and demonstrations the intention is to a scale up to the order of 500 MW electrolysis capacity and to scaling up to 3-4 GW in 2030. The presentation of the current situation illustrates that many activities are already being carried out to facilitate the development of hydrogen but there are barriers.

This concerns themes such as policy, legislation and regulations, market organization, safety, social embedding, hydrogen market and certification, development and organization of the manufacturing industry, innovation and human capital. Fast decision-making management on these topics – which often have a long lead time – are necessary to be able to realize the ambitions for hydrogen.

1. Markets for Green hydrogen are not yet or insufficiently developed. There are not complete value chains of climate-neutral hydrogen that are necessary for markets to function properly yet. Demand development for climate-neutral hydrogen in industry and upscaling is desirable to make chains work and to reduce costs.
2. In addition to a lack of availability of Green hydrogen, the cost difference with Grey hydrogen and the lack of appreciation for climate-neutral products by downstream customers is currently an important bottleneck for industrial bulk users, while the tools for this (e.g. subsidies and obligations) are not available yet or has an insufficient price (e.g. the EU ETS emissions trading system). This has a big impact for the developments in transport and mobility.
3. An open access and connecting infrastructure between potential markets, large-scale production, import and storage is not available yet and connections to the important demand markets, such as Germany and Belgium, are not ready yet. Related to this, the way in which hydrogen can be transported on a large scale, such as liquid, gas formation or bound to organic components (liquid organic hydrogen carriers) is studied. The mentioned HyWay27 offers recommendations for this barrier.
4. The required human capital (HCA) is not sufficiently available yet. This applies across the entire spectrum of hydrogen chains (and the broader energy transition) across all facets; the need for well-knowlegded people is big in all over the value chain. Collaboration with technical University's is necessary to tackle this barrier, but also retrain people from the former natural gas plants.

8. Conclusions

The government has set it goals in the Climate accord. To achieve those goals they provide the NWP. The National hydrogen program describes how the implementation will be in the period 2022 – 2025. A conceptual approach is proposed for the implantation. To start with the large scale development of hydrogen in industrial clusters and ports. This contains the three hydrogen valleys: The Northern Netherlands, Port of Rotterdam and Hydrogen Delta valley (South-west Netherlands).

This large-scale track has high priority because new production and demand developments for hydrogen lead to volume, so that infrastructure and storage can also be rolled out, the (Dutch) manufacturing industry is offered an interesting home market and the import and later export function can start to grow. After this decentralized regions can link to the existing backbone to develop regionals hydrogen projects. There is a different between each region. The Northern Netherlands is acknowledged as the leading hydrogen valley in Europe. the region would like to retain this position after 2030 and wants to encompass the entire hydrogen value chain.

This contain access to European Markets, a large offshore wind potential for Green hydrogen, strategic location and knowledge about trade, transport and innovation. The ambition of the area is reflected in the number of projects comparing to the other regions.

Rotterdam is already the energy port of Northwest Europe and is aware of the fact that the largest part will be imported from areas where renewable electricity is much cheaper and where it already is converted into hydrogen. The ambition of the Port of Rotterdam is be an import hydrogen hub for North Western Europe. They focus on building an infrastructure where they can use the harbour to facilitate import, export and distribution of hydrogen in to the European backbone.
The Smart Delta Region represents a Dutch-Belgium cross boarder industrial cluster focused on the implementation of large-scale green (and blue) hydrogen as a feedstock material in the local and other five industrial clusters.

The Gasunie is involved in all the regions and places in the supply chain. Together with a lot of companies they will provide the hydrogen backbone. The Northern Netherlands is the leading hydrogen hub in The Netherlands, in collaboration with the other two regions the Netherlands & Belgium will be ready for a hydrogen future. But before that, some barriers have to be turned into opportunity's. Public-private and regional cooperation must be strengthened in the coming years in order to optimally coordinate the production and landing of sustainable electricity, the production of hydrogen and the demand for hydrogen (inter)regional. To this end, the ministries, provinces, municipalities and regional players will (further) enter into partnerships.