13 August 2022
Article

Hydrogen trade - a prerequisite for net zero in the US and Netherlands

Both the US and the Netherlands are well positioned to contribute to the development of an international hydrogen market and there is ample room for cooperation. This trade mission can contribute to that process

Content

Introduction and key messages

Future trade in hydrogen is one of the key topics of this trade mission between the US and the Netherlands. This article informs the delegates of the trade mission on the major developments in hydrogen in both countries and the long-term prospects for hydrogen trade. It comes with

three main messages:

1. Both the Netherlands and the US have high ambitions for hydrogen production and application.
2. The US is likely to have a competitive advantage in hydrogen production in the long run and could export to the Netherlands.
3. In the long run, a net zero economy requires international trade in green hydrogen.

Part 1. Hydrogen in the Netherlands: ambitious plans to build hydrogen infrastructure but don't forget about hydrogen demand

Hydrogen production

Currently, the Netherlands produces around 175 petajoule (PJ) of hydrogen. In terms of volume, around 7 billion cubic metres are produced in processes where hydrogen is the main product, for example in the production of ammonia (fertilizers) and methanol (chemical industry). In other processes, around 9 billion cubic metres of hydrogen is produced as an inevitable by-product, for example in gasoline production (naphtha crackers) and steelmaking (coke oven gas). In Europe, the Netherlands is the second largest user of hydrogen after Germany.

Almost all hydrogen is produced from natural gas (grey hydrogen), without capturing and storing the carbon emissions (blue hydrogen). With current gas prices at more than 200 euro/MWh, the cost of hydrogen production has increased tenfold.

Development of the hydrogen market

The Netherlands, like many other European countries, has high ambitions for hydrogen. Scenarios for a net zero economy by 2050 point to Dutch hydrogen use of 200 to 900 PJ per annum. But hydrogen production must transition away from grey hydrogen created from natural gas towards green hydrogen production based on electrolysis with solar and wind power. Blue hydrogen can be a transitory solution to lower emissions from natural gas-based hydrogen production, as it captures and stores most of the emissions (CCS).

While 2050 provides a dot on the horizon for hydrogen demand, businesses and policymakers need guidance for the nearer term. That's why the Dutch government has set five important hydrogen targets for 2030:

1 Development of **hydrogen infrastructure** between the main industrial clusters and neighbouring countries by HyNetwork Services, a subsidiary of Gasunie, the Dutch transmission system operator of the gas infrastructure. The infrastructure will be developed in three phases:

- The first phase runs to 2026 and comprises pipelines in the western part of the country to connect the industrial cluster at the coastline (Zeeland, Rotterdam, Amsterdam, Den Helder, Noord).
- The second phase runs to 2028 and comprises eastern pipelines running from Eemshaven in the north (Noord) to the Chemelot industrial cluster in the south (Limburg) and connecting the hydrogen infrastructure in the Netherlands with Germany.
- By 2030, these western and eastern routes will be connected to a southern route that also taps into the Belgium hydrogen infrastructure (third phase near Sas van Gent and Dilsen).

These plans in the Netherlands are part of a larger vision for a European Hydrogen Backbone.

The aim is to have the hydrogen infrastructure between the main industrial clusters and neighbouring countries completed by 2030

Development of hydrogen infrastructure in the Netherlands

Source: Hynetwork Services and Dutch Government

2 **Investment** in the Dutch hydrogen infrastructure is expected to total €1.5 billion of which the government will provide €750 million.

3 Three to four underground **hydrogen storage facilities** will be built in the north and north-east part of the Netherlands using empty salt caverns.

4 In order to make the transition from grey to green hydrogen, the government aims for 500-megawatt **electrolyser capacity** by 2025 and 3-to-4-gigawatt capacity by 2030.

5 To power the electrolysers with **renewable energy,** the government aims for 21 gigawatts of offshore wind capacity by 2030 and 35 terawatt hours of onshore renewable power generation, mostly from solar panels and onshore wind turbines. The Dutch government, for example, is developing coordinated tenders for offshore wind and hydrogen and has provided a subsidy for the world's first pilot with offshore hydrogen production from seawater. Nevertheless, current estimates indicate that the offshore wind target is very ambitious while the onshore target is likely to be met well before 2030.

Three key questions for hydrogen in the Netherlands

While the Dutch show large ambition in building the hydrogen supply chain, three key elements are still an open question:

1. Understandably, the current focus is on building the hydrogen infrastructure. Will hydrogen **demand** in manufacturing, transportation and real estate follow a similar pace?
2. Most hydrogen will still be made out of natural gas in the coming years (grey and blue hydrogen). To what extent will hydrogen production suffer from **skyrocketing gas prices**? And will electrolyser development be impacted by high power prices?
3. Industrialised regions with strong potential to become exporters of hydrogen, like the US, could use a lot of hydrogen to green sectors domestically. To what extent will domestic demand limit hydrogen **trade**, for example from the US to the Netherlands?

Part 2. Hydrogen in the US: ramping up hydrogen efforts and Texas is a promising place to be

Hydrogen production

The US is the second largest consumer and producer of hydrogen behind China. The US produces roughly 10 million metric tons of hydrogen per year, accounting for 11% of production globally. And the development of hydrogen in the US is going to accelerate further.

Development of the hydrogen market

The biggest driver for this projected growth is the Infrastructure Investment and Jobs Act passed last year, which aims to dedicate $9.5bn to clean hydrogen development. Of this, $8bn is allocated to establishing regional clean hydrogen hubs (H2Hubs) across the country in the industrial sector and beyond, $1bn is set to advance the Hydrogen Electrolysis Program and lower the cost of electrolysis and hence hydrogen production, and $0.5bn is targeted at promoting hydrogen manufacturing and strengthening domestic supply chains.

In June, the US Department of Energy (DOE) announced details of the selection criteria for the $8bn H2Hubs programme over the next five years. The DOE intends to grant funding to at least four H2Hubs and there are already several states eying to apply as a coalition or individually. The DOE plans to evaluate proposals based on, among others, energy and environmental justice, labour engagement, job creation, and inclusive workplace building. Additionally, the DOE plans to select hubs that would together form a diverse hydrogen portfolio in terms of feedstock, end use, and geography. The DOE will choose at least one hub that produces hydrogen from fossil fuels (with carbon capture technologies), one from renewables, and one from nuclear energy; it will also grant at least one hub in the power, industrial, heating, and transportation sectors.

Additionally, the proposed Inflation Reduction Act, which has now passed the Senate and is awaiting voting in the House, plans to introduce production tax credits (PTCs) between $0.6/kg and $3/kg for clean hydrogen development in the country. The newly proposed tax credit rules would also include a threshold that eligible clean hydrogen production needs to be able to achieve 56% of emissions reduction compared to grey hydrogen production (using natural gas).

Furthermore, to receive the highest credits, a project needs to emit lower than 0.45kg of CO_2 per kg of hydrogen. Despite the strict qualification provision, the hydrogen PTCs would largely lower the cost of hydrogen production. Bloomberg New Energy Finance estimates that at this PTC level, clean hydrogen production could already be cost competitive with grey hydrogen production.

As of June 2021, the US had 17 MW of electrolysis for dedicated green hydrogen production in operation, with another 1.4 GW of projects in the pipeline and 120 MW at earlier stages of development to come online by 2030. The infrastructure bill and the Inflation Reduction Act will together attract more new hydrogen projects in the US over the next few years.

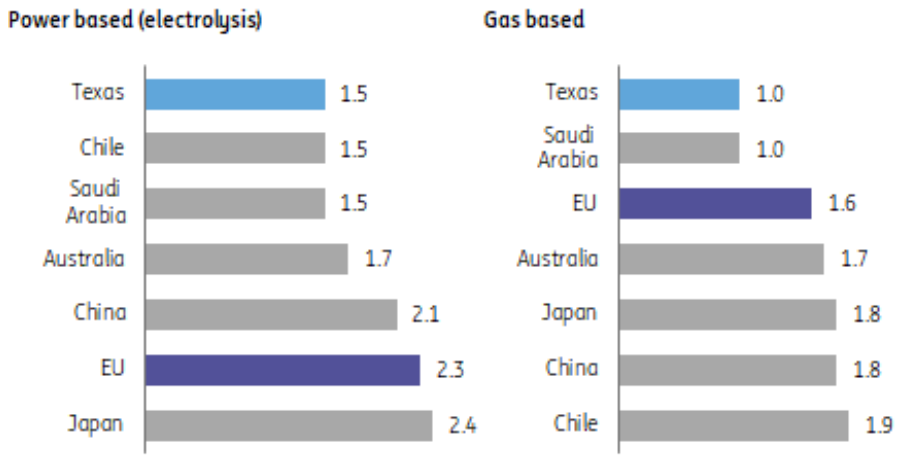
Texas is a promising place to be

There are three reasons why Texas is a promising place to be.

1 Texas is a region with significant advantages for the deployment of hydrogen, especially green hydrogen that is produced using wind power. Texas is abundant in wind power, generating about 28% of the US's total wind-powered electricity in 2020. Because of this, the levelized cost of green hydrogen in Texas is already cheaper than in other regions in the country last year. This year in the US, the cost of hydrogen in late July soared to $16.8/kg, three times the normal price, as renewable electricity prices increased with the surge in energy costs. Yet despite this fluctuation, the cost of green hydrogen is expected to fall 63% globally by 2030 as production equipment and renewable electricity become cheaper. It is forecast that Texas enjoys cost advantages of both green and natural gas-based hydrogen production in 2030 compared to other jurisdictions such as the EU, Australia, and China. Plug Power, the largest electrolyser supplier and developer in the US market, has a green hydrogen production plant in Texas.

Texas production costs in 2030 could be cost competitive in both electrolysis- and natural-gas-based hydrogen

Cost of hydrogen production in USD/kg



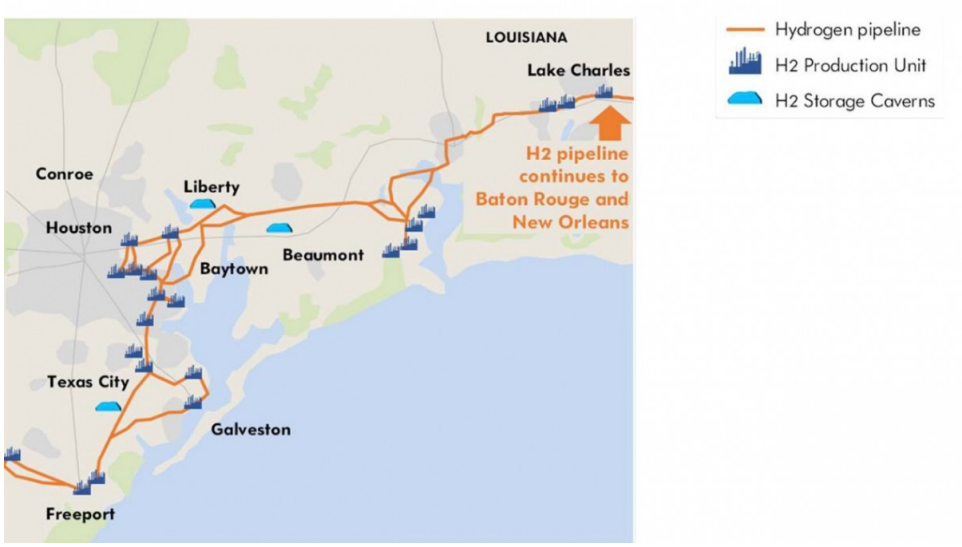
Source: ING Research based on McKinsey

2 A second reason why Texas is a promising place to be is that is it suited for producing blue hydrogen as well. The price of natural gas consumed by power generators in the state is roughly 9% lower than that in the rest of the country, which puts Texas in a favourable position to produce natural gas-based hydrogen with carbon capture and storage (CCS). ExxonMobil is planning to build a 1 billion cubic feet per day blue hydrogen plant that is coupled with a 10 Mtpa CCS facility. The latter is part of ExxonMobil's ambition to establish the Houston Ship Channel CCS Innovation Zone which is expected to capture 100 Mtpa of CO_2. BP and Linde have

also collectively announced plans to produce low-carbon hydrogen at Linde's current facilities using CCS technologies.

3 Lastly, infrastructure makes Texas a promising place to be as the state already enjoys relatively abundant hydrogen pipelines, the most economical infrastructure to transport hydrogen from one place to another. The US has more than 1,600 miles of hydrogen pipeline, the longest in the world, and most of these pipelines are in the Gulf Coast region. Such existing infrastructure is a huge plus for Texas to become a regional hydrogen hub that can connect hydrogen production resources with clusters of end users, both domestically and internationally. Besides pipeline transportation, Texas also has ample experience with storing hydrogen in underground storage facilities.

Hydrogen infrastructure in the Gulf Coast area



Source: McKinsey: Houston as the epicenter of a global clean hydrogen hub, 2022

Despite all these efforts, hydrogen production is still expected to fall short of the net zero goals. By 2030, the projected green hydrogen production capacity (before the announcement of the new funding tax credits) is well under the 44 GW of electrolysis capacity the country will need by 2030 to hit its net zero goals. Hydrogen produced using fossil fuel paired with CCS—with over 13GW in the project pipelines is also projected to be below 2030 net zero goals of almost 50GW, despite the recent acceleration of CCS uptake under the 45Q tax credit programme.

Three key questions for hydrogen in the US

While the United States shows large ambition in building the hydrogen supply chain, three key elements are still an open question:

1. Quite a few states, companies, and public-private partnerships are developing hydrogen clusters in the US. To what extent will these clusters be connected? And will that create an integrated or more local hydrogen market?

2. To really reach the US's pledged level of hydrogen production, the development of hydrogen needs to be coupled with the development of renewable energy as well as CCS. Do these technologies grow to such an extent that they reinforce each other?
3. The US can use a lot of hydrogen to green the industrial sector domestically. To what extent will domestic demand limit hydrogen trade, for example, to the Netherlands?

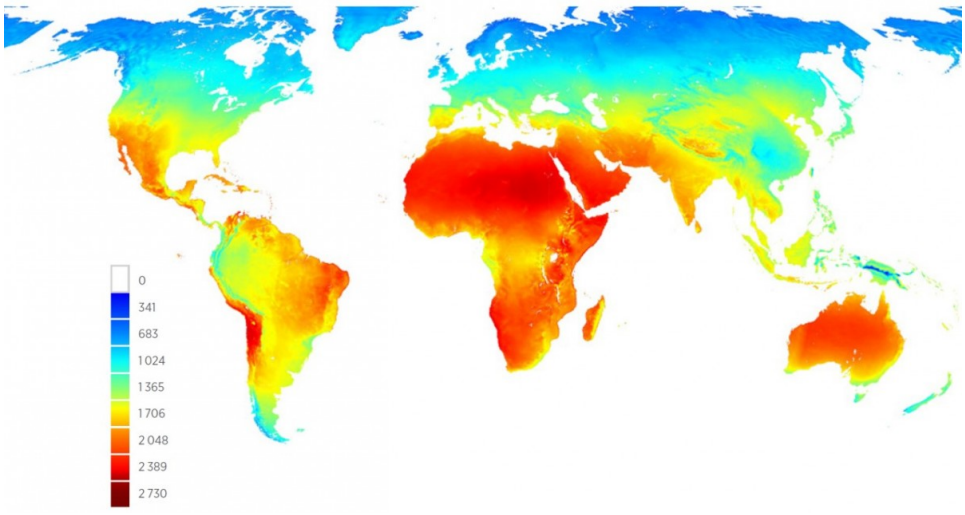
Part 3. Hydrogen trade is still in its infancy

Today, hydrogen is a very local business. According to the International Energy Agency (IEA), about 85% of hydrogen gas is produced and consumed on-site within a facility rather than bought and sold on a market.

Over time, hydrogen could become an internationally traded commodity. Green hydrogen offers the possibility to "ship sunshine and wind", that is, to transport solar and wind energy across borders. The International Renewable Energy Agency (IRENA) vividly shows that different regions have different competitive advantages for solar and wind power.

World solar potential: Texas has a competitive advantage over the Netherlands

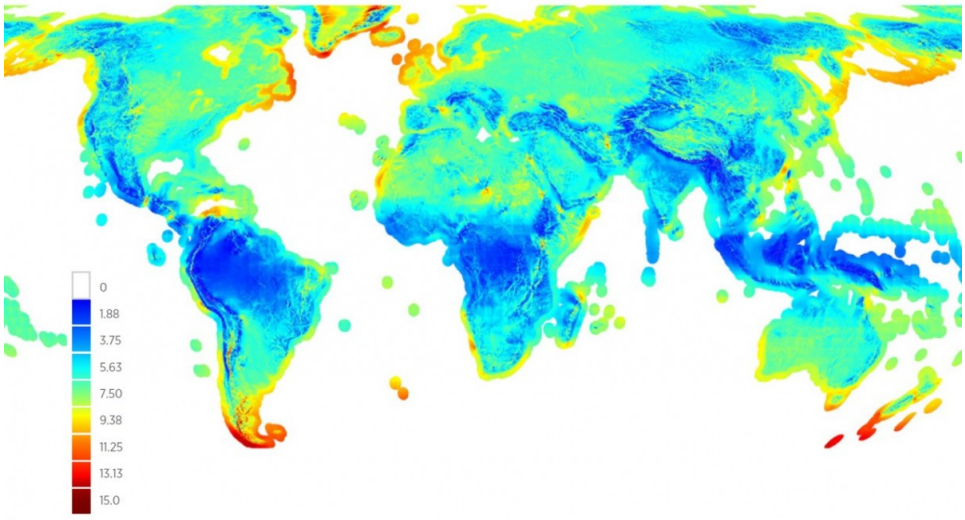
Annual average global horizontal solar irradiation in kWh/m2.



Source: IRENA: Geopolitics of the energy transformation - the hydrogen factor, 2022

World wind potential: Netherlands has a slight competitive advantage over Texas on wind speed

Annual average wind speed at 100 metres in m/s



Source: IRENA: Geopolitics of the energy transformation - the hydrogen factor, 2022

Some regions will have much lower production costs

Due to competitive advantages in solar and wind availability, the levelized cost of electricity from solar panels and wind turbines differs substantially across the globe. Hence, green hydrogen will be most economically produced in locations that have an optimal combination of abundant renewable resources, available land, access to water and the ability to transport and export energy to large demand centres. IRENA estimates that by 2050, green hydrogen can be produced cheapest in Australia and Africa at $0.60-$1.0/kg, followed by Latin America and the south-east region of the US at $0.6-$1.5/kg. Production costs in the northwest European region are expected to be considerably higher at $1.5-$2.5/kg and the region has more spatial challenges to produce large volumes of green hydrogen. Over time, it is expected that these differences make up for the transportation costs of hydrogen and its trading derivatives such as ammonia and methanol.

Hydrogen trade could follow the path of LNG trade

The development and use of new technology can take years to catch on. The LNG market is a case in point. The first LNG carriers left the Lousiana Gulf in 1959 to head to the UK. But it was not until the 1990s that LNG trade grew substantially. And it took a US shale gas revolution before it started to grow exponentially. By that time, gas pipelines, liquefaction and regasification stations, port infrastructure and LNG vessels were developed all over the world to the point that they could spur international trade. Currently, the case for future trade in hydrogen is compelling, but there is still a long way to go before it will be substantial.

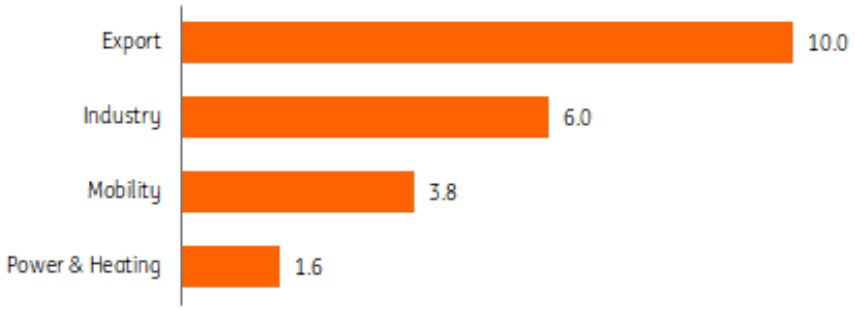
The US is likely to develop a competitive advantage in hydrogen production which could lead to export to the Netherlands

The US does not have an official target or programme specifically for hydrogen trade—nor does Texas. But according to the IEA, the US is poised to emerge as a hydrogen exporter by 2050 thanks to its low cost of hydrogen production from renewable energy and natural gas with CCS. In particular, Texas is seen as having huge potential to become a hydrogen export hub. McKinsey forecasts that Texas will likely be able to export around 10 million tonnes per annum (MTPA) of hydrogen by 2050, provided that its share of global hydrogen remains at

today's level of 4%, or that future exports align with the state's current 8% share of global LNG export. Texas already has the advantage of existing facilities that produce ammonia (a hydrogen carrier for transportation). While the initial exports are looking to be blue because of the abundant access to natural gas in Texas, more exports of green hydrogen will follow suit in the longer term. In 2021, the Port of Rotterdam and Port of Corpus Christi signed a memorandum of understanding (MOU) to collectively develop new technologies such as hydrogen. This will facilitate trade of the fuel in the future.

Demand for clean hydrogen in Texas could reach 21 MTPA, with exports contributing most to demand

Hydrogen use in Texas by 2050 in million tonnes per annum



Source: McKinsey: Houston as the epicenter of a global clean hydrogen hub, 2022

Fostering international trade in green hydrogen

The Dutch Hydrogen Program has identified 10 criteria for the development of an international hydrogen market, preferably with large amounts of green hydrogen:

1. Countries need to have long-term policies to build a hydrogen economy.
2. The availability of green hydrogen for export.
3. Reliable certification for hydrogen, so that users know what type of hydrogen they import (grey, blue or green).
4. Infrastructure to export and import hydrogen (terminals, ships, conversion, storage, pipelines to industrial users).
5. Permitting processes for the import of ammonia which is highly toxic.
6. Permits for nitrogen emissions for the process of cracking ammonia.
7. Development of a wide range of hydrogen carriers such as liquified hydrogen, ammonia, methanol and synthetic fuels.
8. Development of trade channels, which involve for example standardised contracts, exchanges to trade hydrogen, import tariffs and WTO alignment.
9. Incorporation of hydrogen facilities in spatial planning procedures, safety procedures and environmental laws.
10. Financial incentives to build sound business cases that will mobilise the finance to invest in local and international hydrogen value chains.

Part 4. The Netherlands will need to import green hydrogen if it wants to meet EU targets

Hydrogen is likely to play a key role in the transition towards a net zero economy in many countries. If hydrogen production continues to be grey, emissions from hydrogen use will go up instead of down. Hence the European Commission, as part of the Fit-for-55 package, has proposed a target for member states to ensure that 50% of all hydrogen used in manufacturing will come from green hydrogen production.

This target is very ambitious and, according to CEDelft, the impact on the Netherlands will be larger than on most other EU member states due to the large concentration of industries that use hydrogen, such as the chemical industry and refineries. CEDelft analyses three hydrogen demand scenarios for the Netherlands and investigates if the 50% green hydrogen target can be fully met with domestic production or to what extent green hydrogen must be imported. The study concludes that:

- The low-demand scenario requires 80 PJ of green hydrogen production by 2030 to meet the 50% target.
- This low-demand scenario requires an additional 5 gigawatts of onshore wind energy on top of the existing plans to grow current capacity from 2 gigawatts to 21 gigawatts in 2030.
- Most of the available renewable power will be needed to produce green hydrogen, leaving no green power for the electrification of buildings, transportation and agriculture.

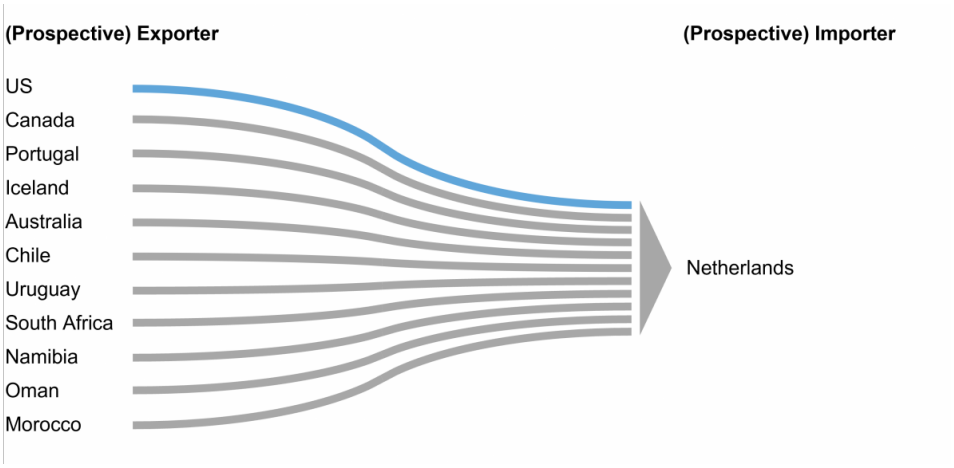
Given the fact that the targeted 21 gigawatts of offshore wind capacity is already highly ambitious and the fact that every sector wants green power too in order to become more sustainable, it is unrealistic that the Netherlands can meet the 50% green hydrogen target without importing large volumes of it. The need to import green hydrogen is even higher in the mid and high hydrogen demand scenarios and if one considers the fact that Dutch harbours

could also import hydrogen for Germany and Belgium, which are also aiming to expand the use of hydrogen. Dutch hydrogen imports could range from 48 to 120 petajoule by 2030, according to CEDelft.

As a result, the Netherlands is partnering with countries all over the world to set up hydrogen trade relations. In 2020, the US and the Netherlands signed a statement of intent to collaborate on hydrogen. The scope of cooperation is mostly limited to information sharing and the assessment of the potential for trade in hydrogen. That should be viewed as the foundational work for a future hydrogen economy. This trade mission could take that a step further. The existing Memoranda of Understanding between the Port of Rotterdam and the ports of Houston and Corpus Christi to facilitate trade only add to that process.

Building hydrogen trade relations

Signed Memoranda of Understandings (MOUs) between prospective hydrogen exporting and importing countries as of November 2021.



Source: ING Research based on IRENA and the Dutch government

Gerben Hieminga
Senior Sector Economist
gerben.hieminga@ing.com

Coco Zhang
ESG Research
coco.zhang@ing.com

Disclaimer