WHITE PAPER

MAKING THE HYDROGEN MARKET

Requirements for the Netherlands to become a hydrogen hub

Royal HaskoningDHV
Enhancing Society Together

Roland Berger

The Netherlands has everything required to become a hydrogen hub, but must act soon to beat competition to the prize

As a natural gas hub, **the Netherlands knows the key success factors** – now it must put these into action

Only the government can facilitate the making of the market, and it should consider acting as market maker or instituting a feed-in tariff

1/ Becoming a hydrogen hub is a necessity, not a luxury

The Dutch Climate Agreement expects that, by 2030, the demand for renewable or low-carbon hydrogen in industrial applications will rise to up to 1 Mton[1] per year in the coastal regions. Fully decarbonizing the Netherlands will require up to 9 Mton per year for energy use and feedstock, assuming biomass use remains at current levels.

Total demand will be even higher if the Netherlands wants to decarbonize our current energy exports to Germany and Belgium, too. To produce 9 Mton of renewable or low-carbon hydrogen per year, the Netherlands would need around 100 GW of offshore wind and electrolysis capacity. It is unlikely that all this capacity can be realized in the Dutch North Sea.

The North Sea Energy Outlook puts the maximum installed capacity for offshore wind at 72 GW, and that would be for both electrons and molecules. Similarly, Germany and Belgium will not be able to achieve full energy independence based on installed renewables alone due to spatial constraints. In short: domestic production will not be enough.

To bridge the supply gap, large-scale import of renewable or low-carbon hydrogen and derivatives will be unavoidable. The Dutch government stresses the necessity to "prepare for both domestic production and import of hydrogen" in its letters to parliament[2] and the European Commission.

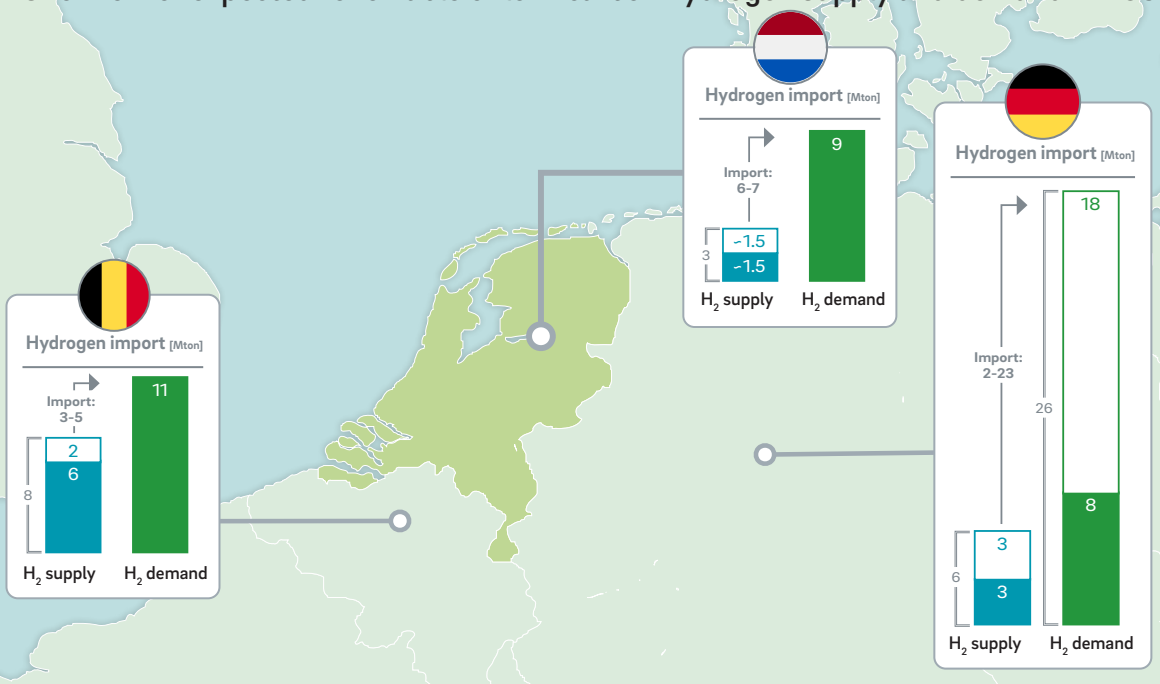
In its recent RePowerEU Communication, the European Commission raised its targets for renewable or low-carbon hydrogen to 10 Mton domestic (EU) production and another 10 Mton in imports, all to be realized by 2030[3]. This will require a hydrogen hub to create a liquid market, where production, import, transit and local consumption all come together in one area or region. ➔ A

[1] https://www.klimaatakkoord.nl/themas/waterstof/documenten/publicaties/2019/06/28/klimaatakkoord-hoofdstuk-waterstof

[2] https://www.tweedekamer.nl/downloads/document?id=d79ea6fb-c670-4f4a-8116-27c6ee57a5cc&title=Marktordening%20en%20marktontwikkeling%20waterstof.pdf; https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2022/03/02/kamerbrief-over-fit-for-55-pakket-waterstof-en-nationaal-waterstof-programma/kamerbrief-over-fit-for-55-pakket-waterstof-en-nationaal-waterstof-programma.pdf

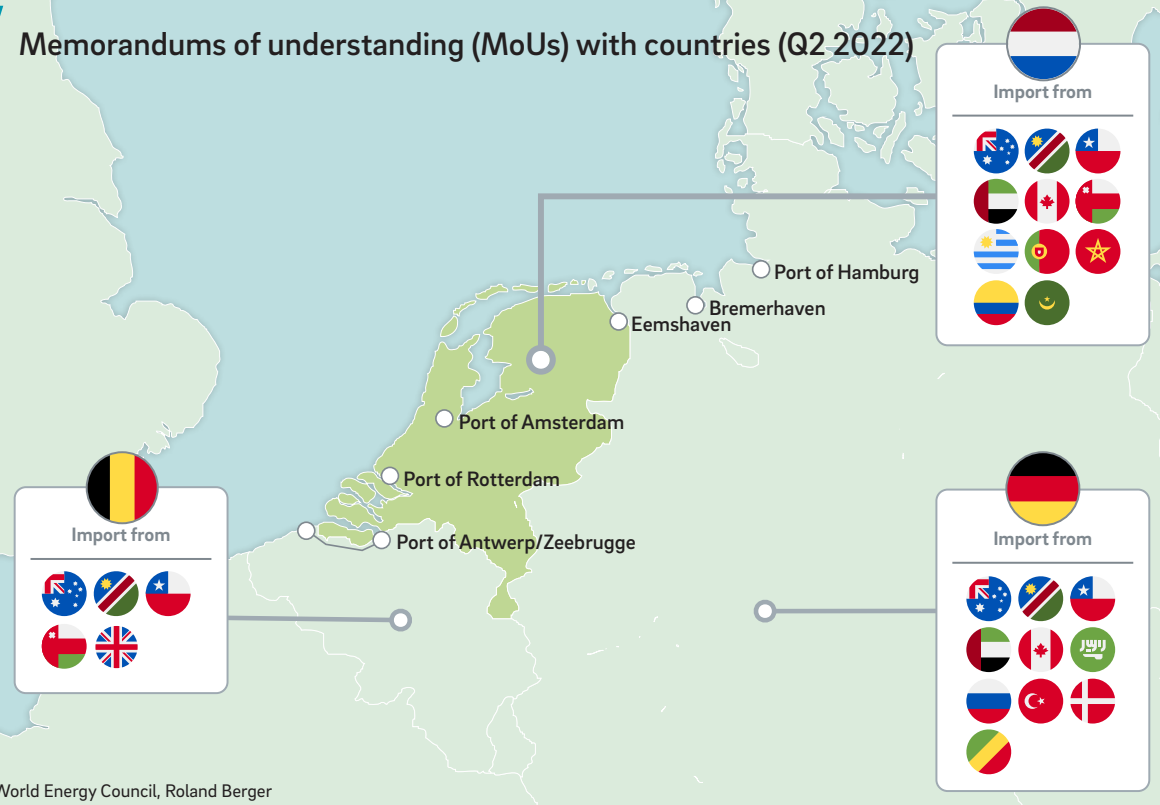
[3] https://ec.europa.eu/commission/presscorner/detail/en/FS_22_3138 brief-over-fit-for-55-pakket-waterstof-en-nationaal-waterstof-programma.pdf

A/ Overview of expected renewable or low-carbon hydrogen supply and demand in 2050



[1] Based on max. half of offshore wind capacity dedicated for H_2 production in 2050 (50% of 38-72 GW), 4,400 FLHs and an electrolyzer efficiency of 70% / [2] Based on demand of 9 Mton H_2 with LHV (33.33 kWh/kg) / Source: Guidehouse, Roland Berger

B/ Memorandums of understanding (MoUs) with countries (Q2 2022)



Source: World Energy Council, Roland Berger

For the Netherlands, becoming that hub would have great advantages, including:

- **Securing sufficient supply of green molecules** for the Netherlands and thus its energy security and independence;
- **Timely decarbonization of current value-added industrial activities** that currently require hydrogen as feed-stock or might require it in the future for high-temperature heating;
- **Attracting new high-value activities** that produce and/or use green chemicals and green materials;
- **Securing and greening jobs** in energy production, transport, storage, transshipment, trade and industry by transitioning from fossil to sustainable energy; and
- **Building knowledge and experience** to ensure key sectors, such as the Dutch offshore and maritime sectors, continue their global, leading position.

More than mere luxury, however, becoming a hydrogen hub is a necessity – if the Netherlands, a major energy hub today, wants to continue to be an energy hub tomorrow.

Multiple initiatives have already started:

- The Port of Rotterdam aims to become "an international hydrogen hub"[4];
- The Hydrogen Delta initiative in Zeeland proposes local production and import to decarbonize its industrial cluster;
- The region around the North Sea Canal (NZKG) wants to import, produce, trade and consume hydrogen at large scale in its Hydrogen Hub;
- Groningen is on its way to becoming one of Europe's first "Hydrogen Valleys"; and
- Gasunie envisions a master plan with offshore hydrogen production sites in the North Sea, piping the fuel to industrial centers through a hydrogen network in the Netherlands and beyond or exporting it[5], and is already planning a hydrogen import terminal with HES International and Vopak in the Port of Rotterdam.

Nonetheless, the government must move quickly, as competitors close to home are eyeing the same opportunity, and – like the Netherlands – are signing memorandums of understanding (MoUs) to secure hydrogen imports.

Belgium, for one, has already signed several (e.g. with Namibia, Oman, Tasmania and Chile) and is working hard to develop large-scale import projects. Germany, too, is trying to secure the much-needed supply by pursuing "Energy Partnerships" around the world, while at the same time pushing its own hydrogen technology abroad. ➔ B

[4] https://www.portofrotterdam.com/nl/haven-van-de-toekomst/energietransitie/lopende-projecten/waterstof-rotterdam
[5] https://www.bloomberg.com/news/articles/2022-01-20/the-netherlands-bets-on-hydrogen-after-natural-gas

2/ The Netherlands has an excellent starting position

Fortunately, the Netherlands has a strong hand to play: it has pipelines and port infrastructure that it can repurpose, and ample potential for hydrogen storage; it is already home to many initiatives in renewable or low-carbon hydrogen production and consumption; and – crucially – it can leverage its experience as a successful hub for natural gas. These are considerable strengths that make the Netherlands well-positioned to beat its competitors to the prize.

Reusable infrastructure

The Netherlands is not starting from scratch. All the ports and facilities currently used by fossil energy can, over time, be made available for green alternatives. This will be a gradual process that could already start with the phase-out of coal. Even now, it is possible to use the existing ammonia terminals at the Port of Rotterdam (~500 kton per year) and Terneuzen for green ammonia imports. ➔ C[1]

The first projects are underway: OCI recently announced it will triple the capacity of its ammonia terminal in the Port of Rotterdam, Vopak is developing an import terminal in Rotterdam[6] for renewable or low-carbon hydrogen imports, and EVOS is developing the project H2A in Amsterdam. There are also many bulk liquid tank terminals with significant storage capacity that provide an opportunity for liquid organic hydrogen carriers (LOHC).

In addition to port facilities, the Netherlands has natural gas infrastructure that can be reused for the large-scale transport of hydrogen. Gasunie currently operates two parallel natural gas networks. It plans to convert one into a dedicated hydrogen backbone that connects all potential hydrogen production and import with key industrial consumer locations before 2030. There is also an extensive offshore natural gas network in the Dutch EEZ that can be repurposed to bring to land hydrogen produced offshore.

Besides the natural gas network, the Netherlands can use the large number of interconnecting pipelines to Belgium, the UK, Germany and Denmark to transport hydrogen. Moreover, the Port of Rotterdam, Chemelot and the German Ruhr area are developing the Delta Corridor, including a set of pipelines for transport of four commodities: hydrogen, CO_2, propane and LPG, and inland waterway links into Belgium and Western Germany. With this infrastructure, the Netherlands can become an important transit country for hydrogen demand in the Ruhr.

Storage capacity

The Netherlands also has sizeable potential hydrogen storage capacity. Most energy scenarios predict that large-scale storage will be needed, and one of the most cost-effective options is to use salt caverns. A typical salt cavern can store 5 kton of hydrogen. The Netherlands, Germany and to a smaller extent Denmark and the UK have significant numbers of salt

structures both onshore and offshore. According to TNO, up to 320 caverns could be made available for hydrogen storage between 2030 and 2050[7/8]. ➔ C²

It is also possible to store hydrogen in existing natural gas storage or depleted gas fields. This brings more challenges, due to the possible mixing of hydrogen with the natural gas that remains. A separation step is likely necessary here, but the volumes that can be stored are much larger – an advantage if the Netherlands is to realize sufficient storage capacity to ensure security of supply.

Salt caverns enable the Netherlands to start storing hydrogen immediately, and over time empty natural gas storage facilities and fields will become available to scale up hydrogen volumes to (nearly) fully replace fossil energy and feedstocks.

Domestic production and consumption

The Netherlands not only has infrastructure with which to begin transport and storage, it also has hydrogen demand and producers that can be connected. ➔ C³

In response to the EU Fit-for-55 package, the RePowerEU package and regional targets, multiple large-scale domestic consumption projects have been announced, including plans to use:

- ~250 kton of renewable or low-carbon hydrogen to produce fertilizers and methanol in response to the new EU target that 35% of all hydrogen consumption must be green by 2030, and 50% by 2035;
- Hydrogen for industrial processes, such as steelmaking; Tata Steel has already committed to converting its coal-based processes to hydrogen and could consume ~100 kton renewable or low-carbon hydrogen by 2030, increasing to 380 kton in 2035-2040;
- 5% sustainable aviation fuel by 2030, 0.7% of which based on renewable fuel of non-biological origin (RFNBO), so on renewable or low-carbon hydrogen (as proposed in the EU Fit-for-55 package). If 0.7% of the aviation fuel bunkered in the Netherlands is produced using hydrogen, this results in a demand of ~12 kton per year; and
- 240 kton per year to replace 2.6% of transport fuels with hydrogen-based synthetic alternatives by 2030 (as required by RED II).

In addition to local demand, nearby North Rhine-Westphalia has set targets for the use of hydrogen in several industrial sectors such as power generation, glass, cement and steel production. Projects targeting the conversion of operations to hydrogen include green steelmaking in Duisburg via direct reduced iron (DRI), a green ammonia and methanol plant, and a turn-around of glass and brick producers. Simultaneously, domestic production of hydrogen is ramping up, with multiple large-scale initiatives already announced with a commercial operations date (COD) before 2030:

- NortH2 and SeaH2land are looking to develop GW+ scale onshore hydrogen production before 2030 using electricity from offshore wind;
- H2opZee plans to develop a 300-500 MW offshore hydrogen demonstration project before 2030. An additional large-scale roll-out of offshore hydrogen production is expected after 2030; and
- More and more 100+ MW projects are being announced and developed, like Shell's Holland Hydrogen I, and last year nine projects applied for an Important Projects of Common European Interest (IPCEI) status.

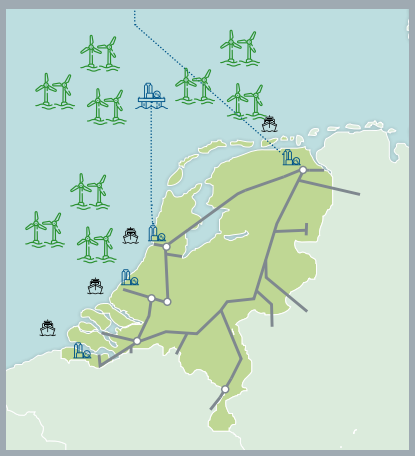
[6] https://www.portofrotterdam.com/en/news-and-press-releases/oci-expands-import-terminal-for-green-ammonia
[7] https://publications.tno.nl/publication/34637700/8sBxDu/TNO-2020-R12006.pdf
[8] https://www.hyway27.nl/actueel/hyway-27-realisatie-van-het-landelijk-waterstofnetwerk

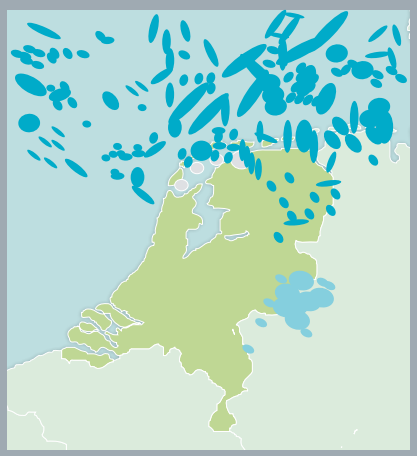
C/ Excellent Dutch starting position

1 Reusable infrastructure

2 Storage capacity

3 Domestic production and consumption





Experience as a successful natural gas hub

The presence of infrastructure, supply and demand for hydrogen is all the more significant because being a successful natural gas hub has taught the Netherlands that these are critical to success.

With the privatization of the gas markets, Gasunie was forced to focus on transport – i.e. hub – services. Even though the UK gas spot market was more advanced at the time, the Netherlands managed to make its TTF gas hub the benchmark for gas trade in Northwestern Europe, mainly due to three key success factors:

- **Infrastructure** | The Netherlands already had extensive, large-scale infrastructure, with a pipeline network, considerable storage, interconnecting capacity to Germany, Belgium, France and later also the UK, and LNG import infrastructure. This infrastructure enabled the physical connection of supply and demand;
- **Liquidity** | There was already significant local production and consumption available in the Netherlands. Large volumes relied on the system, with considerable local supply from the North Sea and Groningen gas fields together with strong demand both in the Netherlands and surrounding countries, which formed the basis of a liquid market; and
- **Trading** | Gasunie set up a digital trading platform that boosted volumes and liquidity, due to easier transfer of ownership, increased numbers of active traders, and limited possibility to manipulate the market, among others. This was combined with the introduction of a tariff system that did not base transport cost on total distance covered, but charged a fixed fee to enter and exit the system. This made the use of the system accessible and cost-transparent for both physical users and traders.

3/ The Netherlands must put key success factors in place now

If experience has taught the Netherlands what it takes to become an energy hub, it must now put these lessons into practice to become a hydrogen hub.

Specifically, it must:

1. Ensure timely availability of large-scale infrastructure

To become a hydrogen hub, the Netherlands must be ready to accommodate large-scale import, transport and storage when and as (international) supply and demand take off. This means that the existing import and transport capacity must actually be repurposed and investments made in additional large-scale domestic hydrogen infrastructure (both onshore and offshore), including storage capacity, new port facilities to accommodate import streams, and interconnectors to the hinterland. Private parties cannot do this by themselves.

There is a clear unit cost benefit when building infrastructure at large scale. However, it is too uncertain when the infrastructure can be used at full capacity, and the upfront investment is too high to develop an infrastructure of sufficient size to achieve those benefits. The government will have to step in, as it did before for natural gas infrastructure.

The government's role will include public investment, but also creating the right conditions such as fast-tracked permitting. Permitting can be sped up by a proactive attitude, competent and sufficient personnel, a flexible design, and a parallel permitting process using digital tooling such as parametric design. This will result in significantly shorter lead times for rework and simplified communication with competent authorities, and will make developing new hydrogen projects faster and cheaper without compromising safety. For an onshore hydrogen network and storage, it seems clear which parties are responsible, but for an offshore hydrogen network and large-scale import infrastructure, the government needs to clarify who will take this responsibility.

2. Facilitate local production and consumption, while attracting global supply

As the example of natural gas shows, if you want to grow into an international hub it helps if you already have a base to start from at home. The Netherlands has that base – with first projects announced for both hydrogen production and consumption – but will need to do more to accelerate those plans into actual and final investment decisions and a real competitive advantage.

The key challenge is to break the deadlock between supply and demand in terms of price, timing and flexibility. From a demand perspective, it is uncertain when the willingness to pay for green end-products is such that it justifies investments and signed offtake contracts – this despite EU ETS regulation and several targets such as those included in RED. On the supply

side, such long-term supply contracts are essential to make necessary investments. Providing governmental financial support to overcome this chicken and egg problem will unlock significant (private) investments on both sides. Support in the form of only investment subsidies (CAPEX support) will not be sufficient, as the operational cost of renewable or low-carbon hydrogen production is currently simply too high. Operational subsidies (OPEX support) are essential.

OPEX support for industrial consumers only will likely prove ineffective as there would be limited incentive to enter long-term contracts. In a few years, when the market would be further developed and more liquid, and the costs of production lower, a better deal could be made.

This not only holds for kickstarting local supply; such support schemes would also be needed to kickstart imports. Having such schemes in place would also be an advantage in convincing key upcoming hydrogen production markets on other continents to steer their energy flows towards the Netherlands. Countries such as Germany and Belgium are already embracing such initiatives like H2Global[9].

3. Set up a digital trading platform and a flat tariff system for infrastructure

A hydrogen exchange must be in place that allows the market to not only physically but also virtually connect supply and demand. This will further aid the development of liquidity in the hydrogen market. Gasunie and four Dutch port authorities are currently exploring such an exchange under the name HyXchange[10].

In addition, a single flat tariff system for the use of infrastructure should be put in place. Private parties would not connect all production, import and consumption, but only parts.

This automatically results in the need for a public hydrogen transport infrastructure with multiple entry and exit points. Especially during the ramp-up of the market, low prices for the use of infrastructure and storage capacity will be crucial, and will accelerate the hydrogen market and thus the Netherlands' competitive advantage in attracting hydrogen import streams.

[9] https://www.h2-global.de
[10] https://www.gasunie.nl/en/news/creation-hyxchange-hydrogen-exchange-a-step-closer

4/ The government should step up to facilitate the start-up of the market

Market parties are unlikely to take up the gauntlet, as buying renewable or low-carbon hydrogen at current costs and selling that to industrial consumers at prices they are able to pay will be loss-making for some time (and no one can say for how long). The government must break the chicken and egg deadlock between production and consumption.

Facilitation by the government is especially needed in the start-up of the hydrogen market until the market has matured, after which the government can step back into a more regulatory role similar to its role in the natural gas market. To do so, different options are outlined in figure D.

The government can start up the hydrogen market in the short term (without relying on the market) by acting as a market maker or instituting a feed-in tariff (options 1 and 2 in figure D). ➔ D1/ D2

Both options are currently being considered by the Ministry of Economic Affairs and Climate Policy[10]. When organizing auctions as market maker – in a way similar to the German H2Global initiative – the government would both buy and sell renewable or low-carbon hydrogen.

By doing so, it could both guarantee the long-term offtake contracts hydrogen producers need to invest in production capacity, and guarantee the supply hydrogen consumers need to invest in decarbonizing their processes.

It would also allow the government to prioritize specific sectors based on the impact (ecological and economic) of greening their operations and the ambition and feasibility of their plans.

The government will absorb the difference between producer cost and industrial consumer price, but it would likely do that in any support mechanism for either producers or consumers.

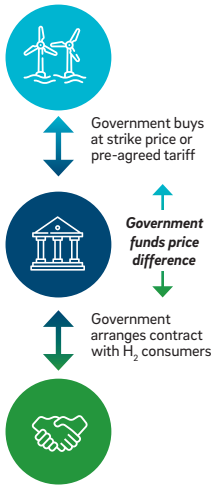
Now, because it is on both sides of the auction and has no profit motive, it can match supply and demand at optimal cost. Any deviations would not end up in the pockets of either producers or consumers, but remain with the government and thus lower the overall cost to society.

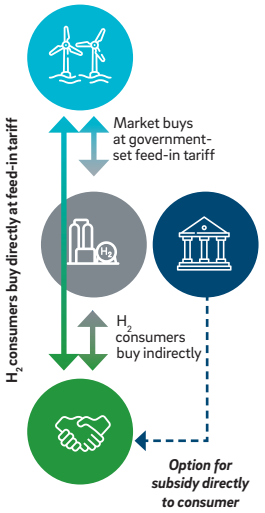
Next to organizing auctions, the government might opt to introduce a feed-in tariff. In that case, the government obliges the market to buy the hydrogen from the producers at a feed-in tariff. By doing so, hydrogen producers are ensured of long-term offtake by industrial consumers at a given price. Also, there is no necessity for the government to first have a subsidy mechanism (and budget) in place. Subsidy directly to selected consumer sectors is, however, still an option.

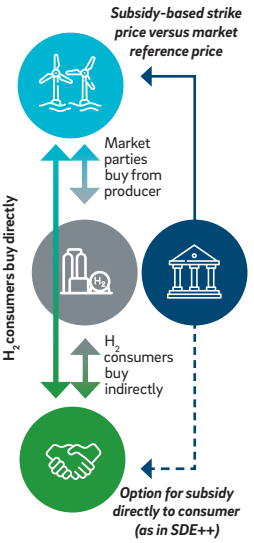
[10] https://www.rijksoverheid.nl/documenten/publicaties/2022/06/02/ontwerp-beleidsprogramma-klimaat

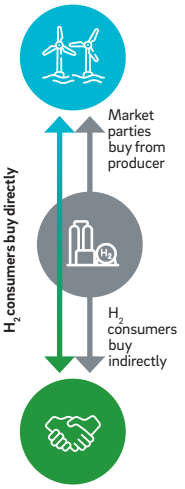
D/ Options to facilitate the start-up of a hydrogen market

	1. Government as market maker	2. Feed-in tariff	3. Contract for difference	4. Subsidy-free
Description	Government at market maker, buying and selling hydrogen, and funding price delta	Government defines fixed tariff for which renewable or low-carbon hydrogen must be purchased	Hydrogen producers selling on the market and receiving a subsidy from the government based on strike price	End goal without subsidies or active market participation
Example	**H2Global initiative in Germany**	**Option mentioned by Ministry of Economic Affairs and Climate Policy**	**Proposed under REPowerEU scheme and in UK**	**Mature and liquid market, e.g. current natural gas market**
Advantages	Active steering on security of supply Long-term contracts for producers, making projects easier to finance Prioritizing consumers possible	Guaranteed prices for producers, making projects easier to finance No subsidies required to reach targets, optional for selected sectors	Increased promotion of competition Limited market interference, as government only pays for delta with market price, limiting chance for windfall profits, especially with a 2-way CfD	No subsidies required No windfall profits from subsidies Full promotion of competition
Considerations	All risks with government, potentially high societal cost Potential slowdown of market trading activities due to strong interference	Potential high margins for hydrogen producers if tariff level is not properly set or updated No steering on security of supply	Potential for high-risk premiums to be include in strike price, as limited projects have been developed Reference price for renewable or low-carbon hydrogen required Limited incentive for consumers for long-term contracts, as future hydrogen prices will be lower Limited steering on security of supply	No steering on security of supply Willingness-to-pay required from hydrogen consumers Limited incentive for consumers for long-term contracts, as future hydrogen prices will be lower









H_2 producer · Government · H_2 industrial consumer · Energy company or trader

In the short term, to start up the hydrogen market, the government should consider acting as market maker or instituting a feed-in tariff.

One of the main considerations is that the tariff needs to be properly set to avoid too-high margins for the producers. This option also gives the government limited steering on security of supply. Additional measures would be required, such as firm hydrogen adoption targets to push consumption of the hydrogen it is subsidizing.

Such targets would allow the government to steer hydrogen supply towards the sectors where hydrogen is the only or most effective solution to decarbonize. This will help increase the willingness to pay, while decreasing the amount of total government subsidy required.

For the mid to long term, the government is expected to (and should) settle on a contract for difference (CfD) system[11] (option 3). ➔ D3

This would interfere least with the market, promote competition, and allow for subsidies to gradually wind down to a subsidy-free system (option 4). ➔ D4

CfDs have already proven very successful in driving subsidies for offshore wind to zero in the Netherlands and elsewhere.

However, if such a system were introduced for renewable or low-carbon hydrogen today, few parties would likely participate in the auctions and high-risk premiums would be included in the bids (after all, the technology risk is still high and there is no liquid renewable or low-carbon hydrogen market in place).

Also, in a CfD the producers still need to find a buyer for the hydrogen. Initially, industrial consumers will have limited incentive for long-term contracts, as future prices are expected to be lower. This would not do much to speed up the development of a proper market and, if risks in the end do not materialize, would result in high profits for a few competitors rather than a vigorous market with many.

If the Dutch government is prepared to take up the gauntlet, facilitate the start-up of the market, put in place the key success factors the Netherlands learned from natural gas, and build on its excellent starting position, the Netherlands can become the European renewable or low-carbon hydrogen hub – with all the considerable advantages that would bring to our energy transition, industry decarbonization and economic growth.

[11] A CfD is a contract between a seller of an underlying product (hydrogen) and the government, where the government pays the seller the difference between the value of the underlying product and a strike price when the value of the underlying product is less than the strike price. Usually there is a cap on the maximum paid (subsidized) amount. In a two-way CfD, the seller has to repay the government at market prices above the strike price. In a one-way CfD, as in the Dutch SDE++ system, the seller does not have to do so.

Authors

Royal HaskoningDHV
Enhancing Society Together

Bart de Vries
Director Business Development
bart.de.vries@rhdhv.com
+31 6 54906426

Juriaan Mieog
Senior Consultant
juriaan.mieog@rhdhv.com
+31 6 15093027

Bastian Knoors
Associate Director Energy & Process
bastian.knoors@rhdhv.com
+31 6 57089957

Roland Berger

Arnoud van der Slot
Senior Partner
Arnoud.vanderslot@rolandberger.com
+31 6 21233033

Bram Albers
Principal
Bram.albers@rolandberger.com
+31 6 23637356

Maarten de Vries
Senior Associate
Maarten.devries@rolandberger.com
+31 6 54228401

Stephanie Lanphen
Senior Consultant
Stephanie.lanphen@rolandberger.com
+31 6 10346078

Arthur Tanis
Senior Consultant

PUBLISHER:

ROLAND BERGER BV
Strawinskylaan 581
1077 XX Amsterdam
The Netherlands
+31 20 7960600