# Hydrogen routes Netherlands

## English version Executive Summary

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Committed to the Environment

# Executive Summary

**International climate agreements require us to transition rapidly to a climate-neutral energy system and recent analyses show that hydrogen can play a key role in this endeavour. Developing a new energy chain involves major investments and risks, however. This study examines the costs and barriers associated with developing three types of hydrogen chain: 'blue hydrogen' (using natural gas), 'green hydrogen' (using North Sea wind power) and 'import hydrogen' (using solar power). The analysis indicates most promise for the 'blue' route for the time being, with industry and power generators as the main consumers. Around 2030 there comes a tipping point, though, when the renewables-based routes become competitive, permitting ever widening use in society.**

The Paris climate agreement demands robust and rapid greenhouse emission cuts. The current Dutch government is aiming for a 49% emission reduction by 2030 relative to 1990. It is also pressing for a further tightening of the European emission reduction target to 55% by 2030 - an interim target on the way to an intended 80-95% reduction by 2050. These figures indicate the magnitude of the challenges we face. Besides massive emission cuts, renewable energy output also needs to be very significantly increased, with a major role for solar and wind.

## Hydrogen as the missing piece of the puzzle

Greater use of wind and solar can in part be achieved through electrification of products and processes, but this brings with it a need for electricity storage and transport for improved matching of supply and demand. Hydrogen (possibly converted to ammonia) is a useful energy carrier that can be readily stored and transported and which can moreover be used in other applications, with zero emissions of $CO_2$ or other pollutants. Driven in part by the recent decline in the cost of offshore wind there is now growing interest in the production and use of hydrogen generated using renewable power. Alternative routes for hydrogen production are also conceivable, though. In this study we therefore explore the feasibility of three promising concepts, taking the year 2030 as a horizon:

- 'blue' hydrogen produced using Norwegian gas, with sequestration of $CO_2$ emissions (CCS);
- 'green' hydrogen produced using power from North Sea wind turbines;
- 'import' hydrogen produced using solar power generated in the Mediterranean basin: 'solar fuel'.

We successively analyse the market potential, supply-chain costs and main potential barriers, using the insights obtained to assess the perspective for rapid development of the respective chains.

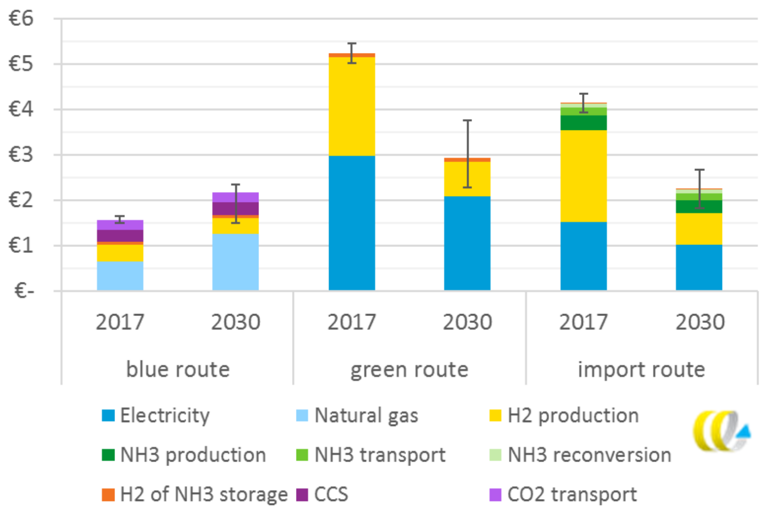
## Market potential

With annual hydrogen production and sales currently standing at 0.8 Megatonne (Mt) the Netherlands already has a substantial hydrogen market, but the untapped market potential is many times greater. Unlocking that potential depends on the speed with which the market can be developed and companies can switch to using blue, green or imported hydrogen. For the 2030 horizon, use in industry (as a feedstock and for high temperature process heat) and for power generation appear to be the most promising applications, implying relatively limited changes in terms of transport systems and process technologies. It may also be possible to develop some potential as a transport fuel, but use as a heating fuel is still in its infancy. Against this background, further growth of the hydrogen market by 0.6 Mt/a (72 PJ/a) by the year 2030 seems readily feasible. Using this volume of climate-neutral hydrogen will lead to a $CO_2$ emission reduction of 5 Mt/a.

## Cost trends

The overall supply-chain costs of the blue route are currently by far the lowest. The price of natural gas is projected to rise in the decades ahead, though, and the supply-chain costs of 'blue' hydrogen will rise accordingly. For the green route and imported 'solar fuel' route the opposite holds. These still involve major capital expenditure, but this will gradually improve and mean that by around 2030 these sustainable routes will be in the same cost range (2 to 3 euro per kg) as blue hydrogen.

**Figure 1 - Projected trends in integral supply-chain costs of the three routes**




## Potential barriers

Over and against these favourable cost projections, however, are technological, economic and social factors that may hold back development of the hydrogen supply chain:

- ***Upstream*** (recovery, transport and production): With the blue route, $CO_2$ sequestration (offshore CCS) may face public opposition. With the green and import routes, cost issues are the main barriers.
- ***Midstream*** (storage and transport): A transport line to bring in hydrogen from the Mediterranean implies major investments and risks, including those relating to possible conversion to and from ammonia.
- ***Downstream*** (distribution and use): At the back end of the energy chain the potential for use in industry (feedstock, process heat) and for power generation is relatively easy to roll out, but in other sectors there are still major downstream hurdles to overcome, in terms of both technology and infrastructure.

## Blue route to pave the way

The analysis of potential barriers indicates that the green and import hydrogen routes still face hurdles in all links of the hydrogen supply chain, while the blue route is already virtually unimpeded, requiring only relatively simple adaptations downstream. The blue route thus enables a rapid kick-start of climate-neutral hydrogen applications in major volumes. This can in turn induce further development of chain segments (especially downstream), which over time will lead to a growing demand for hydrogen, as required. In this 'sheltered' context the production of green and import hydrogen can meanwhile continue to develop apace as investors gain increasing confidence in a growing market for climate-neutral and sustainable hydrogen.

By around 2030 both green and import hydrogen should be sufficiently marketable, allowing further expansion of the hydrogen chain and ultimately allowing blue hydrogen to be supplanted. Given uncertainties in gas-price trends, among other factors, this kind of route to a renewable hydrogen economy will require a certain amount of government guarantees, in the form of support and regulatory measures to incentivize green hydrogen production, for example.