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Management summary

H-vision: kick-starting the hydrogen economy in Rotterdam

The H-vision project has the clear potential to kick-start the hydrogen economy in the Rotterdam area. With the construction and operation of large-scale blue hydrogen production facilities, the industry in Rotterdam will have the ability to make huge strides in decarbonising industrial production processes. This will be achieved by introducing low-carbon hydrogen as an energy source for high temperature heat and power generation.

Sixteen parties have joined forces in the H-vision project. This final report of their study states that it is feasible, from a technical perspective, to use large-scale production of so-called "blue hydrogen" to supply the industry and power sector with low-carbon energy. In order to achieve sound economics and finances, government and/or EU support will be required.

Implementing this blue hydrogen concept would bring the desired hydrogen economy forward by at least 15-20 years and would significantly help the Dutch government to realise the climate change targets set out for 2030. The H-vision project paves the way for a hydrogen economy that will ultimately be based on green hydrogen.

The ambition of the involved parties is to start operating the first H-vision facility late 2025 and increase production capacity towards 2030, thereby offering the industry the option to significantly reduce CO_2 emissions well before 2030. Realizing this project would lead to short-term, large-scale CO_2 emission reductions increasing from 2.2 Mt per year in 2026 to 4.3 Mt per year in 2031 for the reference scope. The CO_2 avoidance costs for this scope vary from 86 to 146 €/tonne (depending on the macro-economic scenario).

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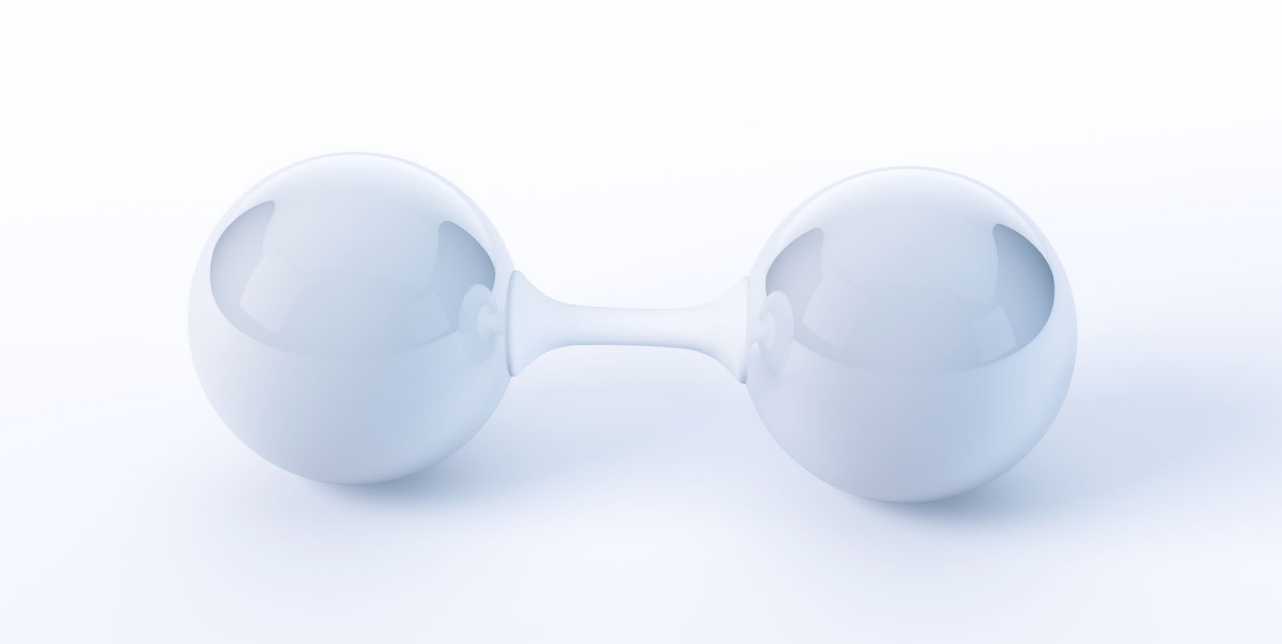
In August 2018, sixteen parties started the H-vision feasibility study with the key objectives to come up with a clear solution to decarbonize high-temperature heat and power generation, realise large-scale emissions reduction, accelerate the energy transition within the industry and find a pathway towards the sustainable hydrogen economy of the future, that will ultimately be based on green hydrogen. This was made even more challenging by imposing the constraint of doing all of this in a cost-effective manner while using existing assets to a maximum extent.

Over time, the project working groups developed deep insights into the concept of using blue hydrogen. This energy carrier would be produced in one or more production plants by reforming large quantities of high-caloric natural gas (hence not the low-caloric gas from the Groningen field) and industrial residual gases into separate streams of hydrogen and CO_2. The blue hydrogen would then be used for industrial processes in mainly refineries and power plants. By doing so, hydrogen could replace natural gas, refinery fuel gas and coal for heat and power generation, and thus help to drastically cut back CO_2 emissions.

The stream of CO_2 resulting from the hydrogen production process is not released into the air, but instead captured and subsequently stored in depleted gas fields under the North Sea seabed (Carbon Capture and Storage). On this topic, H-vision will work closely together with the Porthos project in Rotterdam that is planning to implement a backbone infrastructure to transport CO_2 to the offshore storage locations. The captured CO_2 can also partly be reused, for instance in the greenhouses in the Westland, or exported to other CO_2 storage facilities in e.g. Norway or the UK.



Towards a hydrogen hub

Industrial heat is needed as a stable, constant and predictable flow. This is an ideal basis for a steady commercial market position for H-vision facilities in the short- to medium term. The realisation of the H-vision concept would enable the port of Rotterdam to develop its role as a future hydrogen hub, where hydrogen is produced, used, traded, distributed and imported in large quantities by multiple parties.

A strong upside of the H-vision concept is that the infrastructure developed for transporting and storing blue hydrogen, as well as the technical adaptations required by its users, can be seamlessly used for green hydrogen. Green hydrogen is made using renewable electricity to power electrolysers that split water into hydrogen and oxygen.

The production of zero-emission green hydrogen on a large scale in the Netherlands becomes possible when electricity from wind and solar is available abundantly and against competitive costs. This will likely not be the case in the short to medium term. Blue hydrogen can be made available relatively quickly and will introduce a hydrogen infrastructure that over time can be used for green hydrogen.

The H-vision project is therefore a stepping stone for the future hydrogen economy, paving the road for the large-scale introduction of green hydrogen in due time.

Preferred technology

From a technical point of view, the H-vision approach is feasible and makes optimal use of existing industrial infrastructure. The industrial processes reviewed in this study can switch to blue hydrogen as their primary energy feed. Only limited modifications are necessary for industrial high temperature heating and major modifications are required for power generation, including a challenging transition to biomass as an alternative for coal.

The preferred technology for the large-scale H-vision plant(s) is high-pressure Auto Thermal Reforming (ATR). This approach offers distinct advantages over alternative technologies, primarily with respect to economy of scale and operational flexibility. ATR is not yet a final choice at this stage, as more detailed technical work and cost estimates during the next project phase are required to select the final optimal technology.

To realise this concept in which blue hydrogen substitutes natural gas, refinery fuel gas and coal at a large industrial scale, would require one or more world scale production plants. A single large-scale central production site in the area of the Maasvlakte is envisaged. This enables maximum use of economy of scale benefits, as well as steam and utilities integration with one or more power plants. As the production of blue hydrogen is based on highly mature reforming technology, the scale-up in manufacturing is seen as relatively low-risk.

From a user point of view, the H-vision approach is achievable by using existing industrial infrastructure that will need limited modifications. A key adjustment is that gas-fired burners will have to be replaced by fuel-flexible burners which are suitable for gas with a very high hydrogen content.

The hydrogen will be mainly used in refineries and power plants. Application in power plants seems to be a technically feasible option by either co-firing (next to biomass) or installing additional new hydrogen turbines and connecting these to existing plants. A complexity is that many power plants may have to run as peak-

producers, leading to large and rapid fluctuations in fuel demand. This requires flexible hydrogen production or coupling with hydrogen storage capacity. Combining base-load demand from industry with variable load from the power plants ensures a smoother operation of the hydrogen production plant. This report concludes that a flexible hydrogen supply is achievable.

Development concepts and scenarios

In order to structure the approach of the study, the project team generated four development concepts (*do nothing, minimum scope, reference scope and maximum scope*) that were tested against three different macro-economic scenarios (*As Usual World, Economical World, Sustainable World*).

These scenarios are based on the existing scenarios of the International Energy Agency coupled with specific pricing forecasts that the PBL Netherlands Environmental Assessment Agency developed for the draft National Climate Agreement.

This methodology gave strong insights into which trajectories are feasible and which are not-feasible. Some key features are as follows (only the reference case examples are shown here):

- The H-vision economic feasibility depends largely on the desired rate of return, which reflects the risk profile and political and macro-economic developments, as well as the impact thereof, particularly on the price of natural gas and the price of CO_2 emissions rights. An ETS price of €86 to €146 per tonne is required to make the business case NPV neutral.
- The CO_2 avoidance cost in the reference scope varies from €86 to €146 per tonne (depending on the scenario). This is in fact a strategic investment in building up the hydrogen economy. In all three scenarios the use of blue hydrogen is more cost effective than most of the decarbonization options that are included in the current 2019 SDE+ scheme, for the investigated applications.
- Unit costs for compression, transport and storage of CO_2 are in the range of €17 - €30 per tonne.
- Realizing this project would lead to short-term, large-scale CO_2 emission reductions increasing from 2.2 Mt per year in 2026 to 4.3 Mt per year in 2031 for the reference scope. This case is equivalent to 50% of the current refinery sector CO_2 emissions in Rotterdam.
- The reference scope represents a maximum hydrogen demand of the power sector and industry of just over 3200 MW. In terms of production capacity, this would translate into the construction of two hydrogen production trains with an output capacity of 1460 MW each, which can operate at 110% capacity. Per year, the hydrogen production would then be 700 kt.
- Construction of such production facilities would come with an expected investment figure of €1.3 billion. Including additional costs such as infrastructure, compressors, hydrogen turbines and furnace modifications would bring the total investment figure to approximately €2.0 billion.

It is important to note that at this stage, no development concept has been selected. These concepts and scenarios, including the numbers as outlined above, have been drawn up in order to be able to assess the feasibility in various options, and are not presenting final financial figures.

Next steps

During the next project phases, the team will select the optimum development concept, define the conceptual design, execute the detailed engineering, prepare for the Final Investment Decision and execute the construction of

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the production facilities. The current ambition is to take a Final Investment Decision in 2021 and to start operating the first hydrogen production facility in late 2025.

In the follow-up of this project, there are several challenges to overcome, including uncertainties about commodities and CO_2 emissions rights pricing, but also political direction and macro-economic developments. Support from the public sector in the form of participation, contracts for differences, risk bearing loans or subsidies are required to get H-vision started in view of the non-commercial rate of return on the investment.

Against that background, the parties involved in H-vision will play a key role. Other key roles will be held by the Government as policy maker, insurer & funder, regulator, advocate and facilitator. In the short term, it will be vital to get clarity on political choices for the energy transition roadmap, such as regarding the roles of carbon capture and storage (CCS) and blue hydrogen in particular, but also on the availability of innovative financial instruments.

The taking of further steps by the parties currently involved in H-vision, possibly newly interested parties and the government will all be key in making H-vision a success as the kick-starter of the hydrogen economy in the Rotterdam area.