NortH$_2$

Kickstarting the green hydrogen economy in Northwest Europe

Management summary (EN)

The momentum for hydrogen is unprecedented: countries across the globe have developed hydrogen strategies. They have set targets, committed funding for innovation & scale-up and started the developmet of the necessary infrastructure. We need to accelerate further. By 2050, Europe aims to become the world's first climate-neutral continent. Hydrogen plays a pivotal role in getting there. If we move now we can make it.

The Netherlands, has been an energy hub for Northwest Europe for decades, the acceleration and scale-up of hydrogen provides an economic and strategic opportunity to maintain its position in the energy market, and in key industrial segments. Hydrogen will create jobs, contribute to the Netherlands' future prosperity and is a key lever in realizing the Dutch Climate Accord ambitions for 2030 and towards 2050, especially in decarbonizing the hard-to-abate sectors. Opportunities that will only be unlocked if ambitious goals are set and the current momentum is seized to implement concrete actions. The Netherlands, and specifically the Northern part, has all the ingredients for success, ranging from it's unique location, space availability, infrastructure and storage, ecosystem and off-take potential. However, there is no time to waste.

Scaling up green hydrogen comes with its challenges as new value chains need to be developed: the technology needs to be de-risked, the supply chain needs to be scaled up, a market needs to be established and perhaps most urgently a significant scale-up of renewable power generation is needed. As these challenges are met, new questions will undoubtedly emerge. The NortH2 consortium partners have dedicated themselves to finding answers. Based on the research done in the last 1,5 years, as well as the commitment to further develop the project the coming years, the partners feel confident in the added value of the integrated and programmatic approach that is advocated in this paper. NortH2 can provide the platform for change, for growth towards a green hydrogen economy in 2050. Governmental commitment to these goals, targets and ambitions is needed.

The NortH2 consortium has researched and seen the opportunity to unlock the potential of green hydrogen before 2030 with an integrated value chain approach on the basis of offshore wind fully dedicated for hydrogen production. Integrated projects such as NortH2 are critical in achieving decarbonization via large-scale renewable hydrogen production in time to meet national and European climate ambitions. NortH2 provides enough volume to set up sizeable infrastructure (thereby breaking the chicken and egg problem), it will accelerate the anticipated crucial reduction in the green hydrogen cost curve, and increases the availability and competitiveness of low carbon hydrogen that will lead to an uptake in demand. And it will do so at the lowest cost to society. This is what a big program like NortH2 can put in place.

Below you can find the most fundamental strategic decisions, four of which have been highlighted, that we believe are needed in 2021. They will be further explained in the paper (Chapter 4).

UPSCALING & COST REDUCTION |

- **Government declares the intent to develop the hydrogen economy in the Netherlands in accordance with the NortH$_2$ large-scale programmatic approach and strategic umbrella interlinking technology and supply chain development along the green hydrogen value chain to enable a cost-reduction and scale-up of green hydrogen.**
- Today, there is a cost gap between grey ([redacted]) and green ([redacted]) hydrogen of ca. [redacted] Eur/kg. The integrated and large-scale NortH$_2$ offering can bring down the cost gap between grey and green hydrogen by almost [redacted]

MARKET DEVELOPMENT |

- **A decision to develop the required policy framework (at national and EU level) is needed to incentivize demand for green hydrogen in hard-to-abate sectors.**
  - Although CO_2 prices are expected to rise, this will not be sufficient nor timely to overcome rest of the gap. During scale-up, [redacted] of the cost gap needs to be bridged through market making mechanisms such as (Carbon) Contracts for Difference and/or sectorial market mandates (similar to REDII, but for industry).

OFFSHORE WIND |

- **Additional dedicated offshore wind lots for green hydrogen on top of the existing offshore wind roadmap 2030 should be assigned in 2021.**
  - To reach 55% CO2 reduction by 2030, acceleration of offshore wind development beyond the 10.6 GW already planned is necessary and a no regret measure. As there is a maximum to the amount of intermittent renewable power that can be integrated into the power system, conversion to hydrogen is pivotal to reach the necessary carbon reductions, and specifically needed for hard-to-abate sectors.
  - The Dutch green hydrogen ambition of 4 GW by 2030 should be paired with at least the same amount of additional offshore wind for NortH2 and specifically earmarked for green H2 production. The allocated wind lots should be planned nearby strategic onshore electrolyser (NortH2) locations to enable a power connection landing directly to the electrolysers.
  - The combination of offshore wind production dedicated to the production of hydrogen and the scale of the NortH2 project enable lower societal costs compared to a segmented approach. In the award process, it is crucial to investigate in which way the scale and integrated approach for wind and hydrogen can be enabled.

INFRASTRUCTURE |

- **A mandate for Gasunie and TenneT to support and accommodate the development of the required hydrogen transportation and power infrastructure and also securing a level playing field.**
  - Since existing pipelines are used for realizing a national hydrogen infrastructure, the capacity of this hydrogen grid (~10 GW) will initially be larger than the transport capacity needed by 2030. The costs associated with the excess capacity should not be transferred to the first launching green hydrogen customers. Gasunie is prepared to finance the largest part of the investment and take the associated risk. However, a financial mechanism needs to be put in place to mitigate part of the commercial risks of using existing pipelines and building infrastructure sized fit-for-the-future.
  - To develop the required national hydrogen transport infrastructure Gasunie needs clarity in 2021 that the national backbone will be built connecting with all industrial clusters and storage. This needs to be accompanied by a mandate for Gasunie to develop (in several stages) the backbone.
  - To support green hydrogen, it is important to create a level playing field between green molecules and green electrons through socializing the cost of the power infrastructure, having the ability to reduce the cost of green hydrogen production with another [redacted] hydrogen. This would also encourage the grid balancing function that the integrated 'offshore wind and electrolyser' may provide: (i) the direct connection between the offshore wind farm and the electrolyser (ii) the partial and bi-directional connection between the electrolyser and the national power grid.

The envisioned scale of the NortH2 project is unprecedented. The consortium aims to realize 4GW in 2030, expanding to 10GW by 2040. A significant contribution to the European goal of 40GW in 2030. This asks for partners to think beyond existing boundaries. It requires action today. Systematic research and engineering of all aspects of the value chain are crucial for the next 1,5 years. Final investment decision is, when all the requirements are met, foreseen in 2024.

This policy paper provides an overview of the project development and related requirements known today. Some topics are further matured and detailed than others due to project needs or ongoing policy developments. To achieve the goals, the project NortH2 would benefit from public commitment towards green hydrogen to entice the entire ecosystem to transition away from fossil as soon as possible. The project needs sectorial marketing making mechanisms, offshore wind close to where we can build electrolyzers and where we can start the hydrogen backbone, and TSO's need to be tasked to accommodate the development of the green hydrogen infrastructure.

We recognize the need for innovative alliances with public and private partners in order to accelerate the journey and successful implementation of green hydrogen. In order to realize the hydrogen ambitions and realize this major step into the energy transition; we need to work together. Together we can tackle the challenges we face to develop the energy system of the future.

Samenvatting (NL)

Vertaling volgt

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Contents

1 Introduction

The Ministry of Economic Affairs and Climate (MEAC) has requested the NortH2 consortium to provide an overview of the project development activities and timeline and to highlight the anticipated policy needs arising over the course of the project development. This memo provides the requested information.

The project is in the feasibility phase, which is expected to be concluded mid 2021. That means there are knowns, known unknowns and unknown unknowns. For example, the optimal set of policies to develop the hydrogen market is unknown, but the available policies are known and the consortium will work on quantifying the expected impact of different sets of policy instruments on hydrogen supply and demand in the next few months. From the feasibility work to date, it is clear that the scale, integration and a programmatic approach are important levers to reduce costs and further work is commissioned to understand the ultimate green hydrogen cost levels that can be reached in this project.

We are at the beginning of our journey and don't have all the answers yet. Therefore, we invite you, the government and our future customers to develop this project together: to share the insights we develop along the way, align our approach and activities and jointly accelerate the development of the green hydrogen economy to meet the climate goals.

The memo is structured as follows. The rationale underpinning the need to kickstart the green hydrogen economy through a large-scale dedicated offshore wind to hydrogen approach is described in Chapter 2. In Chapter 3, a project overview is given describing the ambition and design principles, the results of the feasibility study to date, including **cost reduction and scaling up** (3.2.3) and the scope of the work towards end of Q2 2021. In Chapter 4, the various project phases and the anticipated timing are described (4.1) as well as **legislation and regulation** (4.2), **final consumption** (4.4) and **supporting and flanking policy** (4.5).

2 The case for scaling up – now

The EU's aim of climate neutrality by 2050 forces drastic changes in the way energy is produced, stored, transported, used and made accessible. Large parts of the economy – e.g. built environment, passenger vehicles, businesses – can be electrified using (renewable) electricity. For other important parts of the economy – e.g. steel, manufacturing, chemicals, heavy-duty transport, shipping and aviation – direct electrification is not feasible or economic. Low-carbon hydrogen[1] is a solution for these hard-to-abate sectors, as well as a potential solution to store electricity and balance the electricity grid. Demand estimates for hydrogen vary but range from 45 to 70 million tonnes per annum (MTPA)[2] in the EU by 2050 and from 3 to 5 MTPA in the Netherlands.[3]

Today, renewable hydrogen plays a miniscule role in the energy system. Developing the hydrogen economy will require building new value chains. The challenge is massive and encompasses the production, storage and transportation as well as investment and conversion at the customer end. Existing hard-to-abate industries will need to transform their production processes and business models; new industries will emerge.

The Netherlands is well positioned to take the lead in green hydrogen production, due to large areas of prospective low-cost wind North of the Netherlands, the existing gas infrastructure that can be transformed at low-cost into a large-scale hydrogen transportation network, connecting all major NW European demand centres, storage potential and a large (chemical) industry clusters with hydrogen demand.

There are only thirty years left to build the sustainable molecules part of the future energy system. The large-scale development of hydrogen production needs to start now to achieve the NL and EU climate targets for 2030 and 2050, but also to reduce costs through scale and innovation early in the development cycle, to underwrite the investment in the H2 backbone and to seize the associated economic opportunities.

Developing a green hydrogen market requires a dedicated offshore wind-to-hydrogen approach, focused on synchronized development all parts of the value chain directed and facilitated by dedicated government policies. All of this requires close cooperation between customers, developers, suppliers and governments.

The coordinated fast-track development of the hydrogen economy to GW scale through a dedicated wind for hydrogen approach, on top of the existing roadmap, and in line with the Dutch Climate Accord, is what NortH2 is about.

[1] 'Hydrogen' taxonomy in this paper follows the EU taxanomoy as laid out in the EU Hydrogen Strategy 'A hydrogen strategy for a climate-neutral Europe' (2020):

- 'Renewable hydrogen', 'clean hydrogen' or 'green hydrogen' is 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.
- 'Low-carbon hydrogen' encompasses fossil-based hydrogen with carbon capture and electricity-based hydrogen, with significantly reduced full life-cycle greenhouse gas emissions compared to existing hydrogen production.

[2] McKinsey & Company (2020), 'Net-Zero Europe, Decarbonization pathways and socioeconomic implications', p. 137.
Approximately 10 GW of offshore wind (NL sector), fully dedicated to H2 production is required to produce 1 MTPA of green hydrogen (NortH2 calculations)
[3] Gasunie & TenneT (2018), 'Infrastructure Outlook 2050', p.5
https://www.gasunie.nl/en/expertise/system-integration/infrastructure-outlook-2050

3 Project overview

3.1 Ambition and design principles

From inception, the NorthH2 consortium has set the following objectives to frame and guide the development of the project:

- **By 2030,** the project can contribute to achieving the Dutch Climate Accord targets, drive down production cost of green H2 through scale and integration and trigger a NW European H2 backbone.
  → Driving 4 GW by 2030 (0.4 MTPA of green H2 production largely with onshore electrolysis and 3.2 – 4.0 MTPA CO2 abatement, a 100+MW pilot offshore electrolysis will be executed).
- **By 2040**, the consortium will have moved electrolysis offshore at scale to harness wind potential of more remote sections of the North Sea and make the necessary contribution towards establishing a commodity market for green H2)
  → Driving 10+GW by 2040 (1.0+ MTPA of green H2 production and 8 - 10 MTPA CO2 abatement)
- **By 2050**, H2 is an indispensable green molecule in a climate neutral and reliable energy system, having established itself as a commodity in a fully functioning green H2 market.

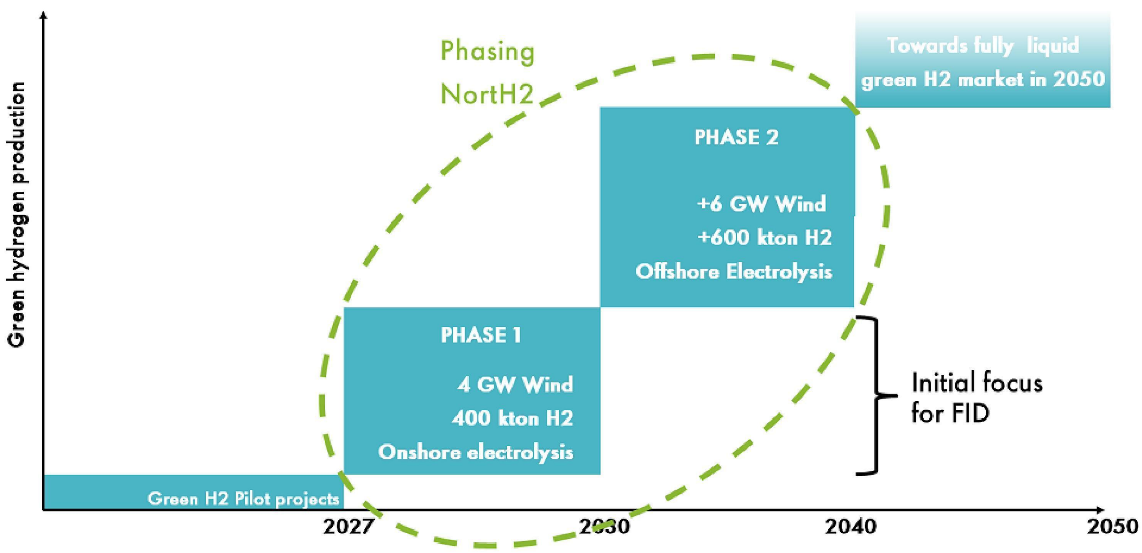

Figure 1 – NortH2 Development Staircase

The project critical path is governed by the first 4 GW of green hydrogen production by 2030. As such, this paper focuses mainly on this first phase as it will offer the platform for further and more autonomous growth of green H2 beyond 2030.

From the outset of the project, the following guiding design principles were applied for Phase 1 (4 GW by 2030):

- Provide a credible pathway to introduce green H2 as an important pillar of the future energy system at lowest cost to society achieving carbon neutrality in 2050.
- As such, provide a no-regret opportunity to kickstart the green H2 economy.

- Provide scale and value integration to significantly drive down cost to supply green H2.
- Primarily target hard-to-abate industrial sectors for which green H2 is the most cost competitive solution to decarbonize and underpin launching demand at scale.
- Produce green hydrogen through water-electrolysis using renewable power.
- As such, a dedicated offshore windfarm will be developed directly coupled to the onshore electrolyser thereby also relieving the public HV power grid.
- Offshore wind farm to be in the prospective areas north of the Northern Netherlands on the top of the current NL Offshore Wind Energy Roadmap (10.6 GW by 2030), fully dedicated to hydrogen production.
- Power produced by the offshore wind farm to be transported through high voltage cables to onshore electrolysers located in the Eemshaven area with dedicated power infrastructure.
- Transportation of produced green H2 to key industrial clusters in NW Europe through refurbished gas pipelines that can increasingly be made available prior to 2030.
- Storage of green H2 in salt caverns in North of the Netherlands to match supply and demand, providing a 100% green flexibility solution.
- Pilot offshore electrolysis (~100 MW).

3.2 Initial feasibility study results (2020)

Together with consultants TNO and DNV-GL, the consortium studied the NortH2 development program to understand the value chain setup and associated levelized cost of hydrogen (LCOH) and accordingly the theoretic market potential to underpin the development. During the first stage of this study, the Phase 1 preliminary value chain (4 GW by 2030) was conceptualized to establish an initial view on the LCOH and corresponding capital requirements. Key insight that emerged is that the scale of the 4 GW program and optimization potential was not fully leveraged both technically or commercially.

Consequently, the consortium commissioned TNO and DNV-GL again to further study the programmatic approach in terms of leveraging scale and technical integration, as well as the LCOH reduction potential provided by commercial optimization. The results strengthen the confidence of the consortium in the potential of the approach with regard to the objectives.

3.2.1 4 GW Design characteristics NortH2 Phase 1

Progressive insights obtained during this study also changed design characteristics and scope of the program. Notably, where initially the consortium targeted a wind area South of Gemini, this later moved to an area North of Gemini (TNW), affecting power cable length and technology choices.

In addition, to accommodate the start-up of the wind farm and electrolyser, to provide grid stability and to accommodate grid and power market balancing, a further electricity connection was added to partially connect the electrolyser to the public HV grid (beyond a dedicated connection between the wind farm and the electrolyser).

This led to the following design characteristics of NortH2 Phase 1 (4 GW by 2030):

Offshore Wind Farm

- Location North of Gemini (TNW) at an average distance of ~130 km from shore
- 4 GW realized in 1 GW steps towards 2030, starting with the 1st GW in 2027

Power infrastructure

- Dedicated offshore power infrastructure from the offshore wind farm to the onshore electrolyser in the Eemshaven area

- Partial connection from the onshore electrolyser to the public HV-grid, to optimize the operation of the electrolyser and at the same time help to balance the grid without causing investments in interregional grid expansion.

Electrolyser

- Electrolyser located in Eemshaven area in 50 to 100 MW modules
- 4 GW realized in 2030 (producing 0.4 MTPA), starting with the 1st GW in 2027
- Compression and processing to meet inlet conditions H2 backbone

Transport

- Backbone that connects all major industrial clusters in Netherlands and interconnectors to Germany and Belgium by 2027 mostly based on refurbished L-gas pipelines.

Storage

- 4 Salt caverns with a total storage capacity of 900 GWh to match supply and demand profiles by 2030.

End-use

- Primarily industrial application (see Market Potential Analysis).

3.2.2 Market Potential Analysis

For industrial applications the competitiveness of green hydrogen vis-a-vis other decarbonization solutions is assessed, based on full value chain cost and technical ability to switch. This analysis showed the potential of green hydrogen for high grade heating and feedstock without carbon requirement.

For high-grade heating, the major advantage of switching to hydrogen is that existing processes can be retrofitted, whereas switching to the all-electric option requires replacement of equipment and electricity grid expansion.

Feedstock applications without carbon can be retrofitted to green hydrogen, such as part of the hydrogen supply to refineries for hydrocracking or hydro treatment.

The time-to-market for the above two sectors is less than five years with an estimated potential demand of 1 MTPA in the Netherlands, equating to a green hydrogen development based on 10 GW offshore wind. This excludes potential in e.g. Germany and Belgium for which the assessments are being developed.

3.2.3 Cost reduction and scaling up

A key part of the NorthH2 value proposition is to significantly reduce LCOH based on leveraging scale and optimization across the value chain both technically and commercially.

The TNO/DNV GL study showed that LCOH can be reduced by [redacted] in total, of which [redacted] is contributed by the programmatic approach, i.e. scale and technical integration and [redacted] by commercial optimization.

Programmatic approach

The programmatic approach is a long-term and strategic umbrella interlinking technology and supply chain development along the green H2 value chain and that aims at achieving large-scale impacts based on strategic partnerships. Since the cost of hydrogen supply is a combination of capital, operational cost and energy efficiency, all levers to reduce cost or increase energy efficiency have been mapped and evaluated for potential to reduce LCOH, for example:

- *Offshore Wind Farm*: Significant reductions in OPEX through pooling maintenance, reduction in CAPEX through the aggregated 4 GW manufacturing and construction program, potentially augmented by new installation methods.
- *Electrolysers*: Progressive cost reductions due to modularization, standardization, (semi-) automation and optimization of the required 'Balance of Plant' equipment.
- *Design optimization*: Instead of pressurizing the electrolysers at 30 barg, designing these at 3-5 barg which will decrease electrolyser CAPEX, with only a limited increase in compressor CAPEX.
- *Operational algorithm*: Load prediction and optimization of the electrolyser stacks to increase energy efficiency and reduce stack maintenance.

Commercial optimization

In the initial design configuration, the electrolyser was directly coupled with the 4 GW offshore wind farm with no connection to the grid. This means that the electrolyser load profile would follow the wind profile and often times, when the wind load is low, the electrolyser would not be fully loaded or even stand idle. In this set up, the capacity factor (utilization) of the electrolyser would equate to 57% or ~5000 full load hours per year.

During the study a partial grid connection of 1 GW was modelled to understand the contribution towards reducing the overall LCOH through increasing the electrolyser utilisation. To maintain the green and renewable character of hydrogen produced by NorthH2, the model was limited to only buy solar power produced in the Netherlands at times spare electrolyser capacity was available, bounded by the size of the partial grid connection. In case that would be economic, the model would also sell green electricity on the power market. Low power prices would typically indicate abundance of electricity and high prices at shortage. In that regard also the ability to balance the power system using electrolysers becomes apparent. As such this set up can also alleviate grid congestion by having the ability to electively increase or decrease the electrolyser load. As a consequence the connection will help to balance the grid without causing investments in interregional grid expansion. With an increasing share of renewable energy sources supplying the power market as the energy transition unfolds, the ability to balance the power grid and market through installed electrolyser capacity will also have an increasing value uplift in the green hydrogen business case.

3.2.4 Levelized cost of green hydrogen

Figure 2 shows the breakdown of LCOH for NorthH2. The cumulated capital investment for NorthH2 Phase 1 (4 GW by 2030) amounts to approximately [redacted] (over the period 2024 – 2030) with costs related to power ('power infra') excluded; it is assumed that these costs will be socialized and where appropriate passed-on to the consortium via a transmission tariff. The development of hydrogen infrastructure (transport & storage) is also out of scope, as it is expected that these are open-access and cost will be shared with other users.

Without the programmatic approach, commercial optimization and any level playing field or other policy provisions the LCOH for the 4 GW value chain by 2030 would amount to approximately [redacted] of green H2. The programmatic approach and commercial optimization would drive down the LCOH to approximately [redacted] and creating a level playing field towards green electricity would further bring down LCOH to approximately [redacted] for phase 1 (from 2027 onwards).

Depending on the willingness of end-users to pay a price premium compared to alternatives, and the development of CO2 prices (ETS), that would still leave a gap that can only be closed by policy.

[redacted]

Figure 2 – LCOH breakdown (using PBL discount factor)

3.2.5 Summary results of feasibility study to date (December 2020)

Technically feasible

- No technical showstoppers identified, but significant technology and supply chain development required

Market

- Green hydrogen can be cost competitive in hard-to-abate industrial sectors against other decarbonisation options if provided with a level playing field.
- Large demand potential identified.
- Potential for green H2 value chain to balance the power market and grid.

High initial costs but potential to reduce

- Main cost components in windfarms and electrolysis; result in a base case price of approximately [redacted].
- Programmatic approach on the basis of a [redacted] program to lower component costs and allow optimization over the value chain to approximately [redacted].
- Providing a level playing field for green hydrogen (socializing the cost of the offshore power infrastructure) can reduce the LCOH towards approximately [redacted]
- Policy measures are needed to close the gap between initial LCOH and the willingness to pay on the demand side (grey + CO2).

3.3 Scope feasibility study towards end Q2 2021

- The program currently being worked by the consortium with delivery by the end of Q2 2021 is aimed at two goals. Firstly, the NorthH2 consortium will demonstrate a credible roadmap towards realising market potential of green H2 in NW Europe. The second goal is to establish a line of sight to a technically feasible and investible business case, working towards an FID in 2024. The remaining work towards end Q2 2021 is broken down into 3 main workstreams with corresponding key objectives:

1. **Technical Development**
    a. Proof technical feasibility: identify at least one overall value chain configuration that is feasible in terms of technology and supply chain readiness and can be delivered within the project critical path and budget
    b. Ensure all scale and integration levers of the 4 GW program towards 2030 have been pulled to meet or exceed the cost target for green hydrogen
    c. Ensure all legal, environmental and local stakeholder requirements have been duly captured in the project development plan
    d. Ensure all technical risks can be managed
    e. Mature the 'Beyond 2030' technical concept based on offshore electrolysis, and develop the pre 2030 pilot
2. **Market Development**
    a. Map out sectorial demand scenarios based on end-user business cases and identify required market making mechanisms, confirming the competitiveness of green hydrogen in hard to abate sectors and associated implementation at lowest cost to society
    b. Produce the full range of market development scenarios and establish both sectorial and overall green hydrogen implementation plans with necessary enabling policy instruments identified
    c. Optimize the overall value chain configuration leveraging the partial grid connection and hydrogen storage to further drive green hydrogen production cost
    d. Maximize the value and benefits of green hydrogen implementation to society
    e. Identify launching customer base and move towards letters of intent to underpin market interest
3. **Policy Development**
    a. Identify level playing field policy framework based on sectorial market implementation scenarios and closing the overall value gap
    b. Gain support for green hydrogen pathway towards 2050

4 Policy development in relation to project development

To manage a project of this size and complexity, the consortium partners are using an integrated stage-gate project management framework. This framework is an industry standard and best-practice in capital intensive projects across industry. It is a project management technique in which a project is divided into distinct stages or phases, separated by decision points known as gates. At each decision point, continuation of the project is decided or re-considered. The decision is made based on forecasts and available information, including the business case, risk analysis, and availability of necessary resources including anticipated governmental decisions.

Energy transition projects such as NorthH2 have an additional layer of complexity: the business case and project risks are driven by an ambiguous policy landscape – both at national level as well as EU level. It is apparent that one project will not drive the timeline on policy development. However, at the request of the Ministry, it is insightful to share what the project needs at each stage in terms of policy clarity. NorthH2 with 4 GW in 2030 can materially contribute to the Dutch and European hydrogen ambition, starting in the Netherlands and Germany. Thinking about what needs to be in place in 2021 and the following years to enable such a contribution in 2030 will not only benefit the NorthH2 ambition – it will also support other hydrogen projects in development and provide a useful starting point for a public-private collaboration and dialogue around policy development.

As described in '3.1 Ambition and design principles', the NorthH2 consortium has ambitions to realize 10+ GW offshore wind and 1+ MTPA green hydrogen production by 2040. Phase 1 of the project is 4 GW offshore wind and green hydrogen production via onshore electrolysis by 2030. The immediate activities predominantly concern the development of Phase 1.

Figure 3 displays the integrated stage-gate project management approach towards realizing Phase 1. As the project progresses through the stages, the commercial/engineering work is matured, risks are detailed, quantified and managed and uncertainty in the business case is reduced.

The two key milestones for the project (FID and First Hydrogen) are set by two drivers. Firstly, NorthH2 would like to contribute to the European, the Dutch and German hydrogen ambitions set for 2030 and therefore has an ambitious construction speed of 1 GW / year starting with the 1st GW in 2027. Secondly, looking at offshore wind, the typical project execution from FID to first power takes about 3 years. This puts FID in 2024. At FID, the typical uncertainty in the business case is 10% or less. That means that, in order to take FID by 2024, the consortium should have clarity on key aspects of the policy and regulatory landscape at that moment.

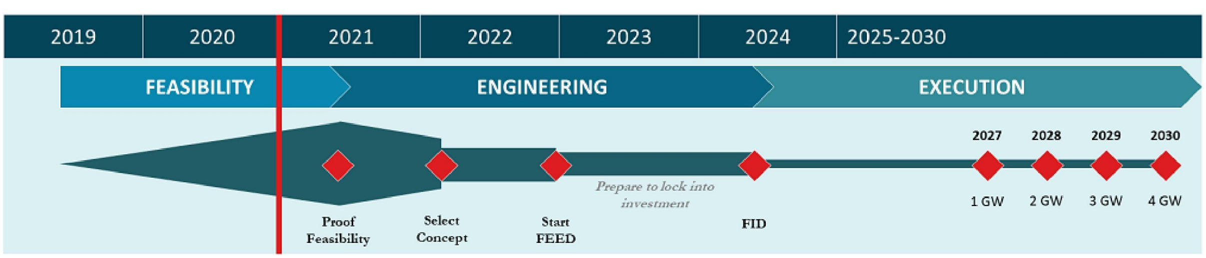

Figure 3 – NorthH2 Phase 1 integrated stage-gate project management framework

How to use table 1?

The integrated overview of project maturation and the policy needs are captured in Table 1. It is the overview of the sections in this chapter. The first row, highlights the project milestones and timeline. The integrated and programmatic approach also applies within a stage. Looking at the first column and bullets in Table 1, the availability of the offshore wind plots dedicated to hydrogen production, will make the NortH2 opportunity feasible or infeasible. Hence, this is captured as part of the feasibility phase. The exact location of the wind plot will determine seabed conditions, cost of the windfarm construction, the size and cost of the power transmission system, wind turbine size, etc. These elements may impact the concept of the project development and hence are captured in the phase 'Select Concept' in the second column.

Details are provided in the following sections:

- Section 4.1 provides an overview of the NortH2 stage-gate approach including an associated budget indication and project timeline. In relation to each stage-gate and for each component in the value chain, the associated policy instruments and political decisions are identified. For the sake of clarity descriptions and explanations are kept short in this paragraph.
- In the remainder of this chapter political decisions in association with the project stage-gates process are detailed out. The policy instruments are discussed following the 'four policy pillars of focus' analogue to the Dutch 'Government Strategy on Hydrogen' (4.2) Legislation and regulation, (4.3) Cost reduction and scaling up green hydrogen, (4.4) Sustainability of final consumption and (4.5) Supporting and flanking policy.[4]

[4] Kamerbrief over Kabinetsvisie waterstof (2020) https://www.rijksoverheid.nl/documenten/kamerstukken/2020/03/30/kamerbrief-over-kabinetsvisie-waterstof

Table 1 Policy development in relation to project maturation

Phase 1 **Project milestones**	**2021** --------------- **Demonstrate** feasibility Fundamental strategic policy decisions	**2022** --------------- **Select concept** before detailed engineering	**Mid** 2022 - 2024 --------------- **Final Investment Decision** 4 GW Offshore wind and electrolysis by 2030
Offshore wind	▪ Identify at least a 4 GW offshore wind lot above NNL on top of the Offshore Wind Energy Roadmap 2030 ▪ Decision to dedicate (identified) offshore wind plots for hydrogen production ▪ Commence design of allocation and award mechanism of dedicated 'wind+H2' offerings	▪ Offshore wind lot designated to NortH2. ▪ Allocation mechanism implemented. ▪ Start permitting and award process.	▪ Offshore wind secured for green hydrogen. ▪ Sufficient outlook on offshore wind expansion capacity for green hydrogen.
Infrastructure	▪ Socialize power infrastructure costs to maintain level playing field between green electrons and hydrogen Power infrastructure ▪ Clarity on the TSO role regarding the electrical direct connection between the offshore windfarm and the onshore landing. ▪ Clarity on the TSO role regarding the onshore electrolyser – grid connection. Hydrogen infrastructure ▪ Provide Gasunie with the mandate to support and start to develop the required infrastructure in stages. ▪ Determine backbone phasing. ▪ To support FIDs for the first stages a financing mechanism is agreed and approved.	Power infrastructure ▪ Ensure spatial planning process to accommodate power tracés Hydrogen infrastructure ▪ Develop a hydrogen specifications and standards	▪ Clarity on roles of TSO's and mandate to operate public hydrogen transport infrastructure
Market development	▪ Decision to develop policy framework (at national and EU level) to incentivise demand for green hydrogen in selected hard-to-abate sectors	▪ To certify the carbon content and origin of hydrogen, a GoO system is implemented. ▪ Start of legislative process on policy to incentivise sectoral demand trough specific instruments (e.g. targets).	▪ Legislative process completed and implementation started
Electrolysers; upscaling and cost reduction	▪ Governmental support for a large-scale programmatic approach	▪ Targeted instruments to stimulate cost reductions, upscaling and innovation to support the large-scale programmatic approach	▪ Targeted instruments granted
Hydrogen storage	▪ Government decision on developing hydrogen storage capacity	▪ FID for first two caverns and above ground-installations	▪ FID for other caverns and above ground-installations
International cooperation	▪ Further strengthening the NL energy hub function, decision to support international trade of green hydrogen	▪ Ensure match legislative and regulatory frameworks between neighbouring countries to support cross-border green	Legislative and regulatory frameworks adjusted and aligned

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4.1 NorthH2 stage-gate approach

The NorthH2 project development can be divided in four stages as displayed in Figure 3.

DEMONSTRATE FEASIBILITY | DECEMBER 2020 – MID 2021 | BUDGET: €[redacted]

NorthH2 is in the middle of the feasibility phase. In this phase, the opportunity is studied from all angles: technically, costs, economics, potential end-users and the policy landscape. Based on the insights provided through the studies, the key ambitions and design principles are set for the project (Section 3.1 and 3.2). At the end of this stage, there is a good understanding of (i) what it takes to realise a robust, investible project and (ii) that realising the necessary conditions is realistic and *feasible*.

From a government policy perspective, we believe that the following fundamental strategic decisions are needed in 2021:

- Government declares the intent to develop the hydrogen economy in the Netherlands in accordance with the NorthH_2 large-scale programmatic approach and strategic umbrella interlinking technology and supply chain development along the green hydrogen value chain to enable a cost-reduction and scale-up of green hydrogen;
- Additional dedicated offshore wind lots for hydrogen on top of the existing offshore wind roadmap 2030 should be assigned in 2021;
- A decision to develop the required policy framework (at national and EU level) is needed to incentivize demand for green hydrogen in hard-to-abate sectors; and
- A mandate for Gasunie and TenneT to support and accommodate the development of the required hydrogen transportation and power infrastructure and also securing a level playing field.

Mid 2021, at the end of the feasibility phase, and the start of the development of the technical concept, certain prerequisites need to be in place to enable a positive stage-gate decision. An overview of these prerequisities is provided below. Each element refers back to bullets provided in Table 1.

Offshore wind

- The 'decision in principle' to dedicate offshore wind lot for hydrogen on top of the existing offshore wind roadmap 2030 should be made. To underpin this decision, we believe that:
  - Offshore wind sites should be located north of the Northern Netherlands - planned nearby strategic onshore electrolyser (NorthH2) locations to enable a power connection landing directly to the electrolysers.
  - The size should at least match the national green hydrogen ambition of 4 GW. The awarding of offshore wind plots and associated green hydrogen production should allow for the necessary cost reduction economies of scale.
  - The offshore wind lot should be designated for hydrogen production and the integrated link between offshore wind and electrolysers should be explored through dedicated 'wind+H2' awarding processes.
  - Government should start preparation of award process and permitting process (e.g. indicate lot, develop required permitting for lot, etc). All to enable the NorthH2 project timeline, which are tied to the national / EU green hydrogen ambitions.

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- In light of this paragraph we welcome the plans of MEAC to further develop various potential tender options for combined offshore wind and hydrogen, based on the initial assessment done by Guidehouse. We are available to contribute to this process by leveraging insights from the NorthH2 feasibility study.

Power Infrastructure

- Clarity on the offshore power TSO role regarding the electrical direct connection between the offshore windfarm and the onshore landing; Who will design and operate the offshore electricity connection?
- Clarity on the TSO role regarding the partly onshore electrolyser grid connection.
- Alignment of decisions with relevant anticipated European frameworks.
- Feasibility established of power transmission to Eemshaven / Groningen.
- Initiate the necessary steps for spatial planning and permits for realizing infrastructure to accommodate power tracés.

Hydrogen Infrastructure

- A 'decision in principle' on developing the national H2 backbone should be taken. As soon as possible after that the backbone phasing should be determined. The phased development of the backbone sections should be aligned with the market development approach.
- Gasunie needs a clear mandate to start developing national H2-infrastrucure as legislation is not anticipated to be timely in place. This means the role of Gasunie in public hydrogen transport should be made clear as soon as possible by the government. Decisions should be robust and aligned with relevant anticipated European frameworks. Basic rules and regulation on third party access to backbone should be in place when it is ready for use.
- Because this infrastructure is being built for the future and existing pipelines are used, there will be some pipeline capacity that will not be used in the beginning. In addition to the Gasunie mandate, it is important to understand how to deal with the risk and cost of the unused capacity. To mitigate this specific risk, a subsidy or guarantee of 30-50% of the investment from the government will be necessary.
- To support the FIDs of the first backbone sections, a financing mechanism for developing hydrogen infrastructure should be agreed, approved and in line with EU regulations.
- A clear view on the hydrogen market design would be welcome. It should highlight the future roles and responsibilities of market and regulated players in the production and supply of hydrogen (who can own, operate and offer integration services to the market), set clear rules for the injection of hydrogen and state specific rules for connecting electrolysers to the grid.

Market Development

- A decision to develop the required policy framework (at national and EU level) to incentivize demand for green hydrogen in hard-to-abate sectors (for more details, see *Section 4.4* Sustainability of final consumption: Creating a green hydrogen market).

Electrolysers; upscaling and cost reduction

- Governmental support for a large-scale programmatic (electrolyzer) approach and strategic umbrella interlinking technology and supply chain development (for more details, see *Section 4.3* Cost reduction and scaling up green hydrogen).

Hydrogen Storage

- Timely decisions are needed to be able to develop hydrogen storage infrastructure. It takes five to seven years to develop salt caverns and the above ground installations. Decisions need to be taken early in the process. Gasunie aims to take FID's in 2021 and 2022.
- Start of the mining permit and spatial coordination (RCR, rijkscoordinatie regeling) process.

International Cooperation

- Further strengthening the NL energy hub function, decision to support international trade of green hydrogen.

DEVELOP & SELECT CONCEPT | MID 2021 – 2022 | BUDGET: € [redacted]

Once the basic design principles are distilled from the feasibility studies and the principle policy decisions are in place, the project can move to *Concept Development.* The goal of this stage is to select the best technical concept based on a broad evaluation framework.

The prerequisite for this work is that fundamental strategic decisions have been made such as the mandate of the TSOs is clear and the strategic policy direction is set. During this phase more detailed studies commence regarding the commercial venture structure, the end-user needs, the vendor ecosystem, potential electrolyser technologies, operating modes, etc. A number of technical concepts are explored and at the end of the phase, the most optimal concept is selected.

Concept Select: this milestone marks the moment that the high-level project design elements are fixed. In addition to the development of the technical concept, and the policy landscape, the commercial agreements start to take shape. The certainty of (un)favourable conditions for an investible project increase significantly throughout this phase and as much certainty as possible has to be attained on the bullets addressed below. It is key that the offshore wind area is secured.

Once the concept is selected, the frame has been set. Between that moment and FID, the project team "works the details". This *detailed engineering* phase requires a massive ramp up of resources (€ X00 mln). It is time to detail out the project: the subcontractor ecosystem is set up, the first signatures are set. In this phase, the selected high-level project design is detailed to a level that allows for construction of the project. For instance, binding long-term Sales and Purchase Agreements are in place for nearly all the hydrogen to be produced (similar to PPAs for wind developments). The goal is to get to a level of detail, commitment and certainty that allows for the final investment decision (FID).

Offshore wind

- Offshore wind lot designated. The wind concession allows for a dedicated wind for hydrogen development.
- Allocation mechanism implemented.
- Permitting process is on track and no showstoppers identified: Timeline aligned with delivery of first GW in 2027.
- Site preparations planned and on track for first GW in 2027.
- The IPCEI status is awarded to the Dutch proposal, this helps the project as f.e. lots can be awarded as part of IPCEI.

Power Infrastructure

- After the role of the offshore power TSO is broadened, take the next step in design of Power Infrastructure. In this phase ensure spatial planning process to accommodate power traces.

Hydrogen Infrastructure

- Develop hydrogen specification and standards, for example, the pressure regime, allowed impurities and their thresholds, standard contracting templates etc. This specification should align with NW Europe countries to ensure that hydrogen can flow cross-border.
- First FID's of staged development of the backbone are taken.

Market Development

- To certify the carbon content and origin of hydrogen, a GoO system is implemented.
- Start of legislative process on policies to incentivize green hydrogen demand in hard-to-abate sectors.

Electrolysers; upscaling and cost reduction

- The preferred concept of the electrolyser will be further developed in 2021. Innovation will take place within the project from 1 GW towards 10 GW in 2040. Targeted instruments to stimulate cost reductions, upscaling and innovation to support the large-scale approach should be provided.

Hydrogen Storage

- FID for first two caverns and above ground-installations.
- Financial mechanisms to mitigate the commercial risks of building storage for the future, that is not completely used in the beginning.

International Cooperation

- Ensure match legislative and regulatory frameworks between neighbouring countries to support cross-border green hydrogen trade

FINAL INVESTMENT DECISION | 2024 | BUDGET € [redacted]

The largest evaluation takes place at FID: technical concept, cost levels, schedule, economics and risks are understood, allowing the consortium partners to take the decision to invest in the project, the *Final Investment Decision*. Subsequently, the construction phase completes the project development cycle. The project will come on-stream in phases, the first GW being planned in 2027.

For FID, the following boundary elements need to be in place:

- Offshore wind (GW scale) secured for green hydrogen
- Award process finalized, and NortH2 successful in securing offshore wind for hydrogen concessions
- Sufficient outlook on offshore wind expansion capacity for green hydrogen (post 2030)
- Clarity on the roles of the future H2 TSO to operate public hydrogen transport infrastructure
- Legislative process completed and implementation started to secure market development
- Target instruments (to reduce costs of electrolysers) are granted
- FID for other caverns and above ground-installations has been taken
- Legislative and regulatory frameworks are adjusted and aligned for international cooperation.

4.2 Legislation and regulation

The anticipated NortH2 set up involves the following three infrastructure interfaces[5]:

1. a direct coupling between the offshore wind farm(s) and the electrolyser(s) to ensure green hydrogen production and reduce potential grid congestion.

[5] For more details see Section 3.1 and 3.2

2 a partial connection to the public high voltage grid (no expansion needed) for operational/ commercial reasons and to allow for grid balancing activities (not to produce hydrogen).
3 a connection to the hydrogen backbone for hydrogen transportation purposes.

Each of these elements requires supporting mandates and regulations to enable smooth integration, reduce inherent project risks and optimize cost reductions. What is common, is that with energy transition projects such as NortH2 the existing regulatory framework does not have the right provisions to kickstart large infrastructure transformations, or quickly assess roles and responsibilities of incumbent TSOs. We believe existing regulations do not provide the mandate for the TSO (on the electricity and future hydrogen infrastructure) and we encourage the government to assess whether the current regulations can be modified to accommodate hydrogen distribution or if a new set of regulatory frameworks is needed[6].

It is the role of the government to orchestrate infrastructure development underpinning energy transition and to enable projects such as NortH2 to come to fruition. We will need governmental and political support to make this project a global flagship project.

These elements are also captured in Table 1 under *Offshore Wind* and *Infrastructure*.

4.2.1 Physically connected electrolyser: Offshore wind

The Dutch government has set a target of 10.6 GW offshore wind in 2030. Greater ambition is needed to meet the Dutch Climate Accord and more will be needed to contribute to the newly released European offshore wind ambition (EU Strategy on Offshore Renewable Energy, 2020) and the North Sea Energy Outlook.

A critical component to the success of this large-scale integrated project will be an assured, timely and direct physical connection of the offshore windfarm(s) to the electrolyser. This provides numerous benefits including operational synergies which can unlock scale of production and cost reductions essential to the success of NortH2 and the Dutch energy transition. Realizing NortH2 on Dutch soil can help the Dutch government build-out their own (offshore) portfolio, secure a competitive position in Europe for offshore wind, hydrogen and the other innovations associated with this integrated project and can also serve to address those potential congestion issues that could arise from power import. Also NortH2 can add to the creation of local employment which in light of economic impact following COVID-19 can contribute to the Dutch economy.

The aim of the NortH2 consortium is to realize 4 GW installed offshore wind capacity before 2030 North of the Netherlands (N-NL) and grow the installed offshore wind capacity to more than 6+ GW after 2030. To realize this, offshore wind lots need to be identified, secured and dedicated for hydrogen. NortH2 is a project with multiple partners that have extensive experience in offshore wind (ranging from Shell Netherlands and Equinor to RWE). To fully unlock the NortH2 potential an award, open door policy, or dedicated/combined offshore wind tender is required to create the integrated value and cost reduction of the programmatic NortH2 approach. The Dutch government can support the market development non-monetary (in-direct support) or directly (subsidies). Another option is to demarcate the consortium controlled or arranged offshore wind build out. Also, an IPCEI status could help realize awarded lots or a bigger part of the value chain.

The cost of construction of the power infrastructure needs to be socialized to ensure a level playing field between electrons and molecules. This is in line with current policies for wind for electricity.

[6] Kamerbrief Rijksvisie Marktontwikkeling voor de Energietransitie (2020)

4.2.2 Grid connected electrolysers: Green hydrogen through Guarantees of Origin

As shared in the design principles Section 3.2.3, NortH2 is anticipating a partial connection to the high voltage grid for operational/ commercial reasons and to allow for grid balancing activities.

In absence of power from the direct connection between the electrolyser and the renewable power plant, the so-called risk of "backfilling" of the grid can manifest itself. Backfilling is said to occur, when a carbon intensive source of power is used (instead of a renewable source) to obtain the required load of electricity to the electrolyser. Especially in areas with a lower penetration of renewable production, backfilling is more likely to occur, especially during periods of low sun or wind.

However, to allow the electrolyser a favourable load pattern, the electrolyser should not be required to 'load follow' the renewable power plant. During summer, there are often extended periods of low wind, severely straining the business case of the green hydrogen producers. Instead, the electrolyser should be allowed to continue to produce at its required load and should be required to prove it only uses renewable electricity. When power intake is from the grid connection, this proof can be provided by retiring an equal number of Guarantees of Origin (GoO) over the amount of power used. This is the only standard of proof currently available to prove renewable electricity was used. GoOs are created by the Renewable Energy Directive (RED) and are the standard across Europe and are therefore an appropriate means to prove only renewable power was used to produce green hydrogen.

When more granular conditions are required to prove only renewable power was used (for example, to use green hydrogen as a compliance fuel towards the RED II Transport target), most preferably the following conditions should apply, to allow the electrolyser sufficient flexibility over its load in order not to undermine its business case:

- The GoOs are still required to be retired, to prevent double counting.
- The temporal matching can be done on basis of meter-based tracking or another industry application, on the basis of transparent production data from TenneT for instance. Currently several early initiatives are under contemplation in various study groups, beside the standard the EC will set for the mobility sector in lieu of the REDII art 27 Delegated Act.
- An accounting timeframe of one month is preferred.
- A geographical scope beyond the Netherlands bidding zone should enable the electrolyser to source renewable power from other bidding zones.
- Allowing a monthly temporal matching, not only ensures sufficient flexibility, but also allows the GoOs to be used for this end, without further amendments to the standard.
- We believe there is no risk of double compensation with renewable power coming from subsidized power plants because the degree of subsidized income of newly awarded SDE++ decisions is reduced with any income over the sale of the GoOs (to the green hydrogen producer).

Similarly, when the electrolyser is directly connected to the wind farm, there may be periods of wind power shortage where power from the grid may be used. The means of proving only renewable power is taken from the grid should therefore be allowed to be used complementary to the proof of using renewable power from the direct connection. By use of solar power from the Northern region the electrolyser may contribute to debottlenecking of the grid in periods of high solar supply.

4.2.3 Hydrogen transport and storage

Having pure hydrogen transport infrastructure in place is a key and critical success factor for NortH2. By 2027, Gasunie could have developed pure hydrogen transport infrastructure (based on its existing natural gas pipelines) that connects all industrial clusters in the Netherlands, including storage and interconnection. Gasunie has already converted its first 12 km natural gas pipeline to hydrogen transport infrastructure in 2018. That pilot-project demonstrates that existing infrastructure can be refurbished for hydrogen transport.

However, there a few prerequisites to enable the development and/or exploitation of the hydrogen infrastructure on a large scale:

1. NortH2 believes that the hydrogen transport- and storage infrastructure should be open to all future users (producers, shippers, suppliers and customers). Thus, the infrastructure should be open-access with NortH2 as one of the launching customers. To ensure this, basic lawsand legislation on third party access and launching customers should be timely in place, especially for transport.

2. NortH2 also believes that hydrogen transport infrastructure should be developed and exploited by an unbundled hydrogen grid operator. That also means that network related activities should be separated from activities open to competition. This is an important step to create a level playing field across market parties engaging in the commercial competitive space and thus driving down costs. Basic rules and legislation covering the market design aspect for transportation should timely be in place.

3. Gasunie will use its existing natural gas pipelines, meaning that the hydrogen infrastructure already has a fixed capacity. Most pipelines that will be used have a diameter of 36 or 48 inches leading to a potential hydrogen backbone with a capacity of 10-15 GW. However, at the beginning of the project not all the capacity will be used and the costs related to this underuse cannot fully be charged to the market. This situation creates a large commercial risk of which Gasunie is prepared to take a big part, but a fall-back guarantee from the government should be in place for some certainty.

4. NortH2 foresees that four salt-caverns need to be developed for hydrogen storage. Developing salt caverns takes considerable time and investment decisions need to be taken even before there is certainty in that largescale electrolyser capacity will be built. It will take Gasunie five to seven years to develop the caverns and the above ground installations. Gasunie expects totake FID's in 2021 en 2022.

Together with MEAC Gasunie is working on HyWay27: a joint effort to investigate how and under what (regulatory and financial) conditions the current natural gas pipelines can be used for the creation of national public hydrogen transport infrastructure. There are three important pillars in the project:

- Usefulness and necessity of national hydrogen infrastructure
- Technical possibilities
- Legal/regulatory and financial conditions

The HyWay27 project is to be finished by April 2021. Swiftly after the publication of HyWay27, government is urged to take a 'decision in principle'to build a national backbone and to develop the legal framework, including support instruments to deal with the value gap described earlier.

In the recently published North Sea Energy Outlook, it is concluded that it is essential to start realizing the infrastructure that is needed for transport of green molecules to end-users, even though there is still uncertainty on the exact development of markets.[7] There are two arguments that highlight why a start is needed: the infrastructure will be necessary and it will take time to build. Using already existent

[7]DNV- GL (2020), 'North Sea Energy Outlook'

infrastructure like natural gas pipelines is seen as an opportunity, both technically as well as from a societal costs point of view. The infrastructure will be rolled out in several steps starting in industrial clusters and growing towards a full national system in 2027. The infrastructure will be built with existing pipelines with a specific capacity. Although using the existing infrastructure is cheaper than using new infrastructure, investment costs cannot fully be transferred to market parties. Gasunie is prepared to invest and take risks for the large part. However, some form of support or guarantee of 30%-50% of the CAPEX is needed to make sure a transport tariff can be put forward to market parties. Concerning this issue, the Minister of MEAC has announced that he is looking into the needed public investments.

We are aware that securing the right rules and regulations in time before FID will be a challenge, partly because the EU framework for rules and regulations will remain unclear. A solution needs to be found to deal with this developing framework. A precedent for the first issue can be found in Gasunie's development of the heat transport network. In that case MEAC gave Gasunie a task to start with the development of the infrastructure in anticipation of a legal task and appropriate regulation.

Next to transport, storage is of eminent importance; not only in relation to the balancing function green hydrogen can provide for the energy system, but also because it enables Gasunie to provide a baseload service of hydrogen transport. The storage infrastructure will be built in a staged and robust manner for growth and future developments. In analogy to the transport infrastructure there are costs that cannot be transferred to market parties and therefore some form of support or guarantee is needed; preferably European funding or national support that fits within a fixed and agreed state aid framework.

The first investment decisions for the staged roll-out of hydrogen transportinfrastructure and storage are expected in 2021 and 2022. However, to be able to create national hydrogen infrastructure that connects all industrial clusters with each other with storage and interconnection the investment decisions all have to be taken in the next four years. That means that a financial support mechanism for the hydrogen transport and storage needs to be in place as soon as possible.

4.3 Cost reduction and scaling up green hydrogen

The success of green hydrogen will depend on the lowest cost for society, meaning the lowest LCOH and the highest spill-over effect to society. As part of the Dutch Cabinet Vision on hydrogen, three levers of success were identified for green hydrogen: upscaling, cost reduction and innovation.[8]

As explained in 3.2.3, NorthH$_2$ has a long-term programmatic approach and strategic umbrella interlinking technology and supply chain development along the green hydrogen value chain. This allows for a cost reduction through two main principles. The large-scale allows economies of scale in all parts of the value chain (e.g. electrolysers, offshore wind), both in CAPEX as well as OPEX. The second one is the integrated design and development, e.g. optimised pressure regime, optimised electrical infrastructure design.

- Since the cost of hydrogen supply is a combination of capital, operational cost and energy efficiency, all levers to reduce cost or increase energy efficiency have been mapped and evaluated for potential to reduce LCOH, resulting in a LCOH reduction of almost 1 EUR/kg (Figure 2).
- The scale of NortH2 incentivizes electrolyser manufacturers to transform their manufacturing process. Today, these manufacturing processes are small scale, non standard and labour intensive. Factories need to be build to accommodate the dramatic step up towards GW scale green hydrogen projects. The ability to further modularize, standardize and automate the manufacturing

https://www.dnvgl.com/publications/north-sea-energy-outlook-192287
[8] Kamerbrief Kabinetsvisie waterstof (2020)

of electrolyzer equipment in dedicated assembly lines provides the biggest immediate opportunity to significantly drive down electrolyzer cost.

- Research and innovation of electrolyser technology will become an important branch of science and technology development. This lays a foundation for future low-carbon, synthetic energy carriers that will be able to contribute to a low-carbon energy supply in various ways. They offer a solution for the future problem of a time- and place-dependent imbalance of electricity. There is scope for innovation on (micro-)electrons, membranes and materials needed for the electrochemical conversion of water into hydrogen (and oxygen). ECCM, TNO and FME have explored the potential of the electrolyser ecosystem in the Netherlands and found 80+ companies and research institutes that either do research, develop technology or provide sub-components to the electrolyser ecosystem.[9,10]
- For scaling up green hydrogen there is a need for funding, e.g. for exploitation. Because the European framework is very relevant in this regard, this point is elaborated in section 4.5.

Although indirect, NorthH2 and other hydrogen production projects have a spillover effect to R&D and innovation. At feasibility stage, it is a challenge to quantify this contribution. What is apparent is that the cost reduction and upscaling through the NorthH2 programmatic approach is significant. This approach is a strategic decision. **The success of NorthH2 will depend on the governmental support that a (long-term) large-scale programmatic approach needs.**

4.4 Sustainability of final consumption: Creating a green hydrogen market

Green hydrogen has an essential role to play in decarbonizing sectors that are hard-to-abate through electrification, especially industry and heavy-duty transport. Given the long investment cycles and complexity of overturning industrial processes, it is essential to incentivize the use of green hydrogen simultaneously with incentives on the production side. A hybrid approach of different policies will be the best option to stimulate a green hydrogen demand in industry. Policies will only be impactful if they are introduced together, i.e. policies on the producer and purchaser alike.

STIMULATE GREEN HYDROGEN DEMAND AND USE IN INDUSTRY

The following policies should be considered to stimulate the demand and use of green hydrogen.

- **Policies that achieve a higher carbon price.** A higher carbon price is crucial for green hydrogen to be considered as a decarbonization solution and the upcoming review of the EU-ETS offers an important opportunity. However, **CO_2 prices will not work to initiate use of green hydrogen market on their own**, they need to be flanked by other policy measures. At this point in time, the CO_2 abatement cost through consumption of green hydrogen is relatively high compared to available alternatives.
- Together with a robust level of carbon pricing, specific policy measures should be considered to drive demand **such as targets for industrial users** set at EU level that promote the uptake of renewables, including hydrogen as defined in the EU Taxonomy. Such targets could drive decarbonization of hard-to-abate sectors such as chemicals and boost the uptake of green hydrogen, sending a clear signal to producers and triggering investments. We recommend that any target should be progressive and achievable. It should be accompanied by policies to ensure adequate supply and alternative means of compliance. The upcoming review of the EU Renewable Energy Directive is an important opportunity in this respect.

[9] Elektrochemische Conversie & Materialen (2017), 'Naar een CO2 -neutrale energievoorziening in 2050' https://www.co2neutraalin2050.nl/docs/reports/advies-elektrochemische-conversie-materialen-eccm%E2%80%93september-2017.pdf
[10] FME & TNO (2020), 'Elektrolysers: Kansen voor de Nederlandse Maakindustrie' https://www.tno.nl/nl/over-tno/nieuws/2020/11/elektrolysers-kansen-voor-de-nederlandse-maakindustrie/

- In parallel, these hard-to-abate sectors should receive policy support to ensure that they are enabled to make the necessary investments for this transition. This could include:
  - **Carbon Contract for Differences (CCfD)** awarded to low carbon material producers (e.g. steel, chemicals manufacturers) based on the volumes of low carbon material produced and attributed via auctions. This mechanism would need to be carefully assessed against other policies and should work in combination with extra CAPEX support to incentivise businesses to switch to low-carbon production processes.
  - Promotion of the use of "low-carbon" and "green" products in end-use sectors. The following policy options could be considered:
    - **Voluntary market initiatives and the use of certificates** for emissions reductions.
    - Strengthen **public procurement rules** (e.g. for low carbon intensity steel) to support early market creation.
    - **Tax credits and incentives** to stimulate customer to purchase products with a lower carbon footprint.
    - Gradual **modification of building codes** to encourage adoption of materials with lower carbon intensity.

Simultaneously, policies to address the risk of carbon leakage should be implemented (e.g., a Carbon Border Adjustment mechanism), as these industries face international competition.

STIMULATE GREEN HYDROGEN DEMAND AND USE IN THE HEAVY-DUTY VEHICLE SECTOR

Green hydrogen is expected to play an important role in decarbonising the heavy-duty vehicle sector. However, this requires **aligning policies that impact vehicles, fuels, infrastructure and customer choice**. It is essential to complement supply policies (e.g. RED II) with demand policies to enable the simultaneous development of hydrogen heavy-duty vehicles (strengthening of the CO_2 standards), hydrogen re-fuelling infrastructure (review of the Alternative Fuel Infrastructure Directive, TEN-E and TEN-T) and green hydrogen supply. Key in creating demand for green hydrogen in this sector is increasing the number of fuel-cell trucks on the road through **mandates on Truck Original Equipment Manufacturers** (OEMs) combined with **fiscal support to lower the Total Cost of Ownership** for customers. In parallel, customer support measures such as tax rebates to encourage the uptake of hydrogen vehicles, financial support for retail sites construction, acceleration of permitting processes as well as policies to enable the development of the supply infrastructure should be in place.

4.5 Supporting and flanking policy; supportive EU policies

NorthH2 supports the EU's Climate Neutrality objective for 2050 and the ambition to increase the 2030 GHG emissions target. As part of the Green Deal agenda, we welcome the EU Commission's Hydrogen Strategy (July 2020). It sets a clear direction of travel, such as the ambitions to have 6GW of installed electrolysis capacity by 2024 and 40GW by 2030.

In addition to those mentioned in the previous section, the following EU policies are important for NorthH2:

- **Funding**: NortH2 is a project that - due to its nature and size – needs more policy instruments than solely public contributions to enable investments. Time-limited subsidies are needed, similar to the instruments that have been used to stimulate the rapid development of offshore wind. We wish to underline that the Resilience and Recovery Fund offers great potential, in particular for cross-border large-scale projects such as NortH2 and we would welcome the Netherlands and Germany joining forces under an IPCEI project which includes NortH2. We would also welcome the NL Government to explore the other relevant funding mechanisms as well as the possibilities becoming available as a result of the review of the Energy and Environment state aid guidelines.

- Swift adoption of the **RED-II delegated acts** establishing flexible and market-based criteria for accounting of the renewable content of green hydrogen and demonstrating additionality.
- **To enable the infrastructure,** review of both TEN-E and TEN-T directives is important also as part of the fit for 55 package. These should enable the development of hydrogen infrastructure along core network corridors, support the retrofitting of existing cross border gas infrastructure (including storage facilities) to transport hydrogen. Next to that it should simplify the Project of Common Interest (PCI) selection processes that reflect the ambitions of the EU Green Deal by incorporating a sustainability dimension based on GHG emissions reduction potential. NorthH2 needs a PCI status to be able to receive CEF funding.
- The Review of the Alternative Fuels Infrastructure Directive (AFID) should lead to the inclusion of hydrogen and hydrogen-based products and fuels as 'mandatory' fuels. Appropriate incentives should be in place at the European and national level (e.g. grants, subsidies, tax rebates) to support the construction of a hydrogen infrastructure network in strategic locations. The already existing co-funding and financing schemes such as Connecting Europe Facility (CEF) should be further strengthened and provide greater funding for hydrogen.
- **To enable the market**, the upcoming decarbonized gas market reform should include principles for the trading of hydrogen such as unbundling; non-discriminatory third-party access to network infrastructure; transparent and non-discriminatory tariffs for access to networks. It should also include a coherent classification system and an EU-wide system of Guarantees of Origin; based on the life-cycle GHG emissions that is consistent with the criteria defined in the taxonomy and Renewable Energy directive.
- **Tax**: the review of the EU Energy Tax Directive should ensure that the European energy tax framework supports uptake of green hydrogen in the EU. The review should not create obstacles but instead incentivize activities such as hydrogen storage and electricity supply to electrolysers. For instance, at the moment, some energy tax regimes were designed without consideration of an energy product (e.g. electricity) being purchased for conversion to another retail energy product (e.g. gas), potentially leading to "double" taxation. The review should ensure that hydrogen is a separate energy carrier, taxed at a zero-ct. A general or partial tax break for tax on energy consumption in general or from the supplementary tax (ODE) to raise the SDE funds, could materially strengthen the business case for green hydrogen.

5 Working together

The energy transition forces a transformation of the energy system towards ultimately green electrons and green molecules, which will be predominantly hydrogen or hydrogen based. The hydrogen economy needs to be built and there are only 30 years left to accomplish the redesign and meet the 2050 climate targets. This huge challenge also offers large opportunities for the Netherlands (and the Dutch economy) and seizing these opportunities will be instrumental in preserving the future earning power of the Dutch economy.

- The production and distribution of green H2 will create thousands of jobs.[11]
- Green chemistry, adding value to green hydrogen molecules, presents a huge opportunity for the Dutch chemical industry, representing about 100,000 jobs.
- Specialized Dutch manufacturers are well positioned to deliver valuable components to the renewable energy industry, representing (tens of) thousands of jobs.[12]

The Netherlands is uniquely positioned with large renewable low-cost offshore wind potential, a natural gas grid that can be refurbished at low-cost for hydrogen transportation, hydrogen storage potential, a large chemical industry, world-class universities and researchers and large, capable companies willing to invest in and deliver the transformation.

We are at a point in time comparable to when we transformed our economy from coal-based to gas-based, with one major difference: we only have 30 years to accomplish the transition and an even smaller window to seize the economic opportunities associated with it and turn the Netherlands into a leading hydrogen economy.

For the Netherlands to meet the climate ambitions set in the Dutch Climate Accord and in the Dutch Hydrogen Strategy and realizing the associated hydrogen opportunity potential can only be accomplished (i) if we accelerate and scale-up now and (ii) if we go for innovative and effective public private collaboration.

NortH2 is more than a project: it is a pathfinder, a proposal to kickstart the acceleration and scale-up of the hydrogen economy together: developers, TSOs, (industrial) customers and the government.

Our approach is to tackle the problem with the result in mind: what do we need to do now to develop the hydrogen economy to meet the 2050 climate challenge at the lowest cost to society? None of us has all the answers, but together we are confident we can find them.

NortH2 invites the Dutch government to work together on developing that roadmap towards an investable public-private project to accelerate and scale up the hydrogen economy in NW Europe.

Over the last couple of months, since the announcement of NortH2, we have closely worked together with the Ministry of Economic Affairs and Climate. A relationship that could be intensified further to speed up the process. Energy transition is a team sport. Only by working together can we tackle the climate change challenges and realize the energy system of the future. Together we can make this happen and pave the way for a truly green future against the Paris timeline and at the lowest costs to society.

[11] CE Delft (2018), 'Werk door groene waterstof'
https://www.ce.nl/publicaties/2202/werk-door-groene-waterstof

[12] FME, Ekinetix, Stratelligence (2019), 'Waterstof: kansen voor de Nederlandse industrie'
https://www.fme.nl/waterstof-kansen-voor-de-nederlandse-industrie
Bart Los and Jouke van Dijk (2020), 'The Employment Impact of the NortH2 Project', Rijksuniversiteit Groningen, in opdracht van Gasunie/NortH2

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List of abbreviations

'Hydrogen' taxonomy in this paper follows the EU taxonomy as laid out in the EU Hydrogen Strategy 'A hydrogen strategy for a climate-neutral Europe' (2020):

- '**Renewable** hydrogen', '**clean** hydrogen' or '**green** hydrogen' is 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.
- '**Electricity-based** hydrogen' refers to hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), regardless of the electricity source. The full life-cycle greenhouse gas emissions of the production of electricity-based hydrogen depends on how the electricity is produced
- '**Low-carbon** hydrogen' encompasses fossil-based hydrogen with carbon capture and electricity-based hydrogen, with significantly reduced full life-cycle greenhouse gas emissions compared to existing hydrogen production.

AFID	Alternative Fuels Infrastructure Directive
CAPEX	Capital Expenditure
EC	European Commission
ECCM	Elektrochemie Conversie en Materialen
ENTSO	European Network of Transmission System
EPC	Engineering and Procurement Company
ETS	European Trading System
EU	European Union
FEED	Front-End Engineering and Design
FID	Final Investment Decision
GHG	Green House Gas
Go**O**	Guarantees of Origin
GW	Gigawatt
HV	High-Voltage (Grid)
IPCEI	Important Project of Common European Interest
LCOH	Levelized Cost of Hydrogen
MEAC	Ministry of Economic Affairs and Climate
MKB	Midden en Klein Bedrijf
MTPA	Million tonnes per annum
MW	Megawatt
(N)NL	(North-)Netherlands
NW	North West
ODE	Opslag Duurzame Energie
OEM	Original Equipment Manufacturer

OPEX	Operational Expenditure
PEM	Polymer Electrolyte Membrane (Electrolysis)
RCR	Rijkscoordinatie Regeling
RED	Renewable Energy Directive
SDE	Stimulering Duurzame Energieproductie
TEN	Trans-European Transport Network
TSO	Transmission System Operator

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