HyNetherlands 100MW

Final report ENGIE Energie Nederland

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2 Introduction/ summary

2.1 Executive Summary

ENGIE has defined a long-term H_2 roadmap for future expansion of the electrolysis capacity at its Eemshaven project site. The 100 MWe ENGIE H_2 plant has the objective to be a fast-track large-scale demonstration project to trigger the H_2 market in the region, and to demonstrate the bankability, scalability and replicability potential at the site, region and throughout EU. The first H_2 use will focus on the refinery sector (e-methanol for maritime applications) and to H_2 for mobility. The objective of the ENGIE H_2 roadmap is to reach 850 Mwe by 2030 and 1.85 GWe by early 2030´s, reaching over 200 ktpa H_2 production, with a diversity of usage from chemical sector to mobility to steel industry and others.

Figure1 : HyNetherlands Roadmap.

The HyNetherlands project (HyNL) aims at developing, building and operating one of the first large scale renewable power to e-methanol production plants in Europe (OCI/BioMCN) by combining renewable RED II compliant Hydrogen from electrolysis (ENGIE) and biogenic CO2 (EEW) captured from a waste-to-energy plant, processing non-recyclable waste, to produce high quality e-methanol and herewith support the circular economy. Although most of the technological bricks of HyNL project have in recent years achieved and demonstrated technological maturity, integrating those bricks in a series of complex processes, in different locations to produce e-methanol at industrial scale has not been proven yet and is considered a major innovation needed to accelerate scaling up the e-methanol market. The Hydrogen production infrastructure will besides also be used to supply Hydrogen to the mobility and possible other sectors.

To deliver these products to the market, the HyNL project includes the following key components:

- A 100 MW_e Hydrogen plant using electrolysis technology, producing approx. 14,100 tons of renewable Hydrogen and 113,000 tons of oxygen per year via the consumption of more than 795 GWh of renewable electrical energy either coming directly from a contracted offshore wind farm or from the grid with Guarantees of Origin. The Hydrogen plant will be built on the ENGIE Eems gas-fired power plant site,
- A carbon capture unit capable of capturing 200,000 tons of CO_2 per year, built on EEW site, of which 77,500 tpa of biogenic CO_2 (corresponding to treatment of non-recyclable waste) is delivered to HyNL, The carbon capture installation will be integrated in two existing waste to energy lines at the existing EEW Delfzijl site.
- An existing methanol synthesis and distillation plant capable of producing 56,000 tons of e-methanol per year from biogenic CO_2 (77,500 tpa) captured from EEW incinerator and renewable Hydrogen (10,500tpa) supplied by ENGIE´s renewable Hydrogen plant.

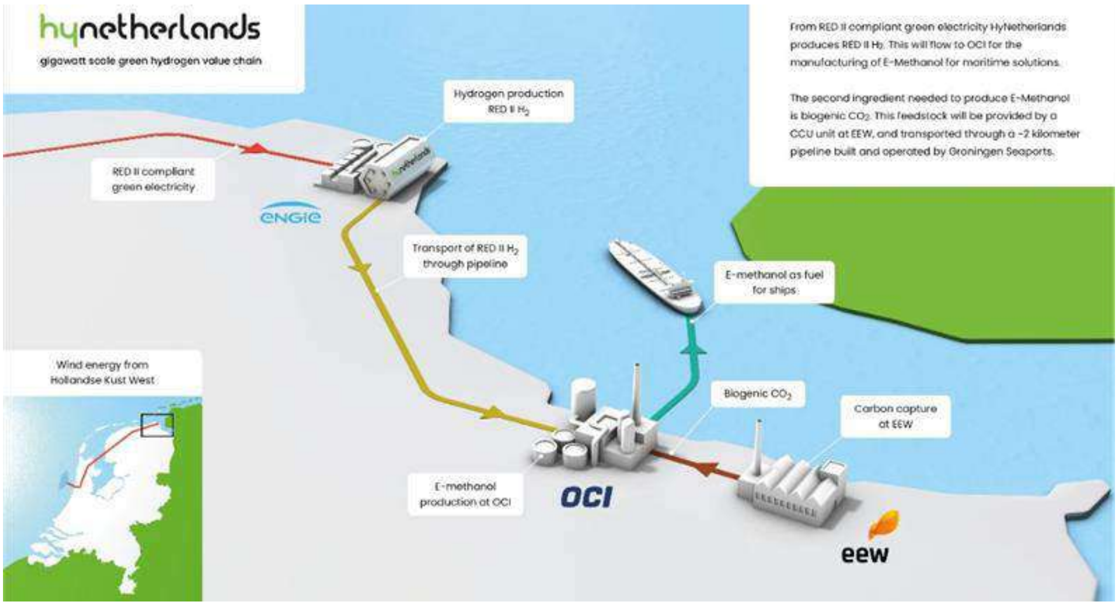


Figure 2: HyNetherlands Value Chain.

Besides these components, the HyNl project will rely on and trigger auxiliary infrastructure investments to be built and operated by third parties such as storage and transport infrastructures:

- the pipeline to transport and temporary buffer Hydrogen from ENGIE Hydrogen plant to the BioMCN e-methanol plant over approximately 20 km, built and operated by Hynetwork Services, Gasunie subsidiary,
- the pipeline to transport CO_2 from EEW Carbon Capture ('CC') plant to the e-methanol plant over 2km, built and operated by Groningen Seaports

- the salt caverns in Zuidwending operated by HyStock, Gasunie subsidiary to buffer Hydrogen capacity
- refueling stations serving the mobility sector.

The anticipated capacity of the e-methanol plant will multiply by 14 the size of current state-of-the-art installations built for similar processes. The CC technology used for this project has demonstrated its feasibility but has not yet been used at this scale in a waste to energy plant with the purpose of supporting an e-methanol production process, which entails associated challenges to be overcome.

The HyNL project has been designed to act as a resilient fast-track development project, by combining (i) resilience with the most stringent criteria which might be imposed by RED2 policy, (ii) resilience to Hydrogen underground storage infrastructure possible delay in development, through linepack storage in the Hydrogen backbone pipeline and (iii) crucial innovations which are present in HyNL project to address key challenges when scaling up the project 8 times by 2030 (mainly relating to intermittency and bankability).

The project triggers also a number of innovations that will need to materialize for the project to be successful in its operational phase. The major innovations, scale impacts triggered by the project are:

1. Implementing and commercializing e-methanol production at large scale (>50kton/y)
2. A 100 MW energy-efficient and fully flexible electrolyzer plant
3. Strong digitalization and implementation of an artificial intelligence enhanced Energy Management System to optimally operate the complete innovative value chain as well as a detailed performance model software
4. Pioneering the usage of regional repurposed and new Hydrogen network infrastructure while using it for storage purposes simultaneously
5. Making a significant volume (ca 3kton/y) of renewable Hydrogen available to the local mobility market (buses and passenger trains) through a tube trailer loading station in Eemshaven

The three partners to this project, ENGIE, EEW and OCI have all conducted their feasibility studies. Based on the results of these studies and the risk mitigation plan, the partners conclude that a sound basis to further develop their respective project is in place.

As explained in the document, the name of the methanol site of OCI, is BioMCN. Throughout the document BioMCN is hence referred to as the e-methanol production site while OCI is referred to as the owner of the plant. While the project main end product will be e-methanol, we will, in the context of HEAVENN, focus in this report mainly on the Hydrogen production part.

2.2 Main project objectives

2.2.1 Project partners

The foundation of the HyNetherlands 100MW project is formed by 3 cooperating parties: (i) ENGIE Energie Nederland NV, (ii) EEW Energy from Waste Delfzijl and (iii) OCI's BioMCN represent an integrated value chain for e-methanol production. A brief introduction;

2.2.1.1 ENGIE Energie Nederland NV

ENGIE Group is a global energy industry leader which traces its origins to the 19th century. ENGIE, together with its 170,000 employees, is committed to accelerate the transition towards a carbon-neutral society, through energy efficiency measures and more environmentally-friendly solutions, reconciling economic performance with a positive impact on people and the planet. ENGIE has 34 GW of renewable capacity in operation and is targeting an additional capacity of 4 GW/year from 2022 to 2025.
ENGIE relies on the collaboration of 4 Global Business Units ("GBUs") – (i) Renewables, (ii) Networks, (iii) Energy Solutions, and (iv) Thermal production & Energy Supply ("T&S") of which the latter GBU is responsible for this project, more specifically the GBU T&S Europe, i.e. Thermal Europe (as it is organized per region). Thermal Europe counts nearly 1,400 employees involved in the development, construction and operations of its centralized power generation assets in Europe and "on site" asset-based solutions for industrial customers. Thermal Europe runs a total capacity of 19.9 GW installed across 7 countries, of which 15.6 GW is gas fired, 3.2 GW is (pump) hydro and 0.2 GW is biomass fired power generation.

As part of Thermal Europe entity, ENGIE Energie Nederland NV ("EEN", Zwolle) will be responsible for the coordination, development, delivery and operation of the HyNetherlands project. In the Netherlands, drawing on the expertise of 180 people, of which 65 permanents at Eems site, EEN manages three Combined Cycle power plants ("CCGT") with an installed capacity of nearly 3 GWe, of which the Eems CCGT represents near 2 Giga Watt electrical ("GWe") of installed capacity. EEN has the responsibility of greening existing fleet and implementing new projects, especially hydrogen production related projects, that support the country's roadmap to carbon neutrality.

2.2.1.2 EEW Energy from Waste Delzijl B.V

EEW Energy from Waste Delfzijl B.V. is a 100% subsidiary of EEW Energy from Waste GmbH, which is located in Helmstedt, Germany. EEW is recognized as one of Europe's leading private companies in the production of environmentally friendly energy from thermal waste recovery. The activities of the company, formerly Braunschweigischen Kohlen-Bergwerke (BKB), started in

1873 with mining production and progressively evolved to enter the business of thermal waste recovery in 1990. In 2003, the company became part of the E.ON group but was sold to private equity EQT in 2013 and acquired by Beijing Enterprises Holding Limited in 2016. Today, with a total of 1,160 employees, the group operates 17 modern facilities – including 15 in Germany, 1 in the Netherlands and 1 in Luxembourg – to thermally process approximately 5 million tons of non-recyclable residual waste (municipal, commercial, industrial) per year for energy production.

EEW Energy from Waste Delfzijl B.V. operates EEW's energy from waste plant located in the Delfzijl industrial park, in the Dutch province of Groningen, the Netherlands. The plant currently has a total capacity of 576,000 tons of waste per year and provides 741,000 tons per year of process steam to industrial companies located nearby as well as 230,000 megawatt hours of electricity per year, which equals to the demand of about 66,000 households. In 2019, EEW Energy from Waste Delfzijl B.V. started to develop a fourth line for mono incineration of sewage sludge, for which permitting and procurement have been successfully completed and construction has begun in order to start operating the plant by 2024. Today, EEW Energy from Waste Delfzijl B.V. has 79 full time equivalent employees.

Within this IF project, EEW Energy from Waste Delfzijl B.V will be responsible for project implementation and operation of the carbon capture plant.

2.2.1.3 OCI's BioMCN

Located at the Chemical Park Delfzijl (The Netherlands), BioMCN is, since 2015, a wholly owned subsidiary of OCI N.V., which has grown over the years from a small family-run construction business, founded in 1950, to a leading global producer and distributor of nitrogen products providing sustainable solutions to agricultural and industrial customers. OCI employs 3,600 people and has a production capacity over four continents accounting for approximately 16.1 million metric tons per year of nitrogen fertilizers, methanol, diesel exhaust fluid, melamine, and other nitrogen products. More precisely, OCI N.V. is globally the 5th biggest methanol producer and the world's biggest bio-methanol producer with a total methanol and bio-methanol production capacity of nearly 3 million metric tons per year.

In Europe, OCI's BioMCN plant has 95 employees and a production capacity of 900,000 tons per year of methanol and bio-methanol making it the biggest plant in Europe. BioMCN was the first company in the world to produce and sell industrial quantities of high-quality bio-methanol, an advanced biofuel, which are produced from biogas sourced from waste streams. The plant has easy logistical access to major European end markets via road, rail, barge and sea freight, allowing it to efficiently reach customers across Western Europe. BioMCN will be responsible for implementing the required technical changes for integrating e-methanol into their conventional production plant and carrying out e-methanol production during the operational phase.

2.2.2 Pillars of the value chain

The integrated value chain of the HyNL project relies on 3 pillars and a unique feature to achieve the following goals;

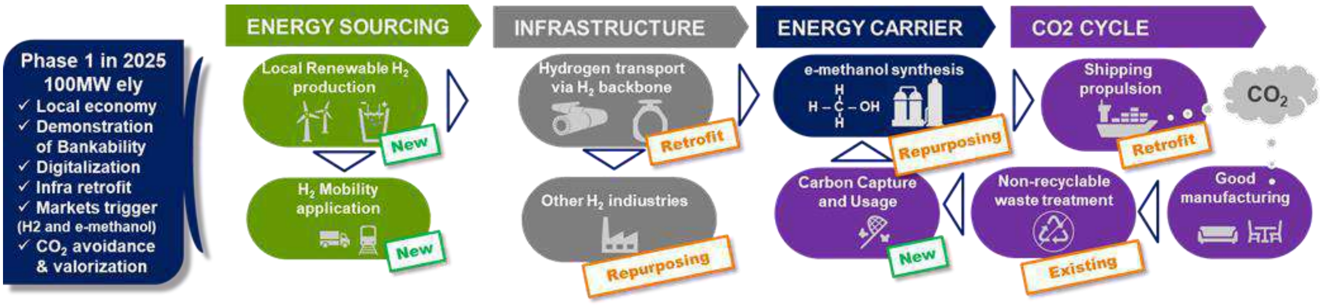


Figure 3: Integrated HyNL value chain.

2.2.2.1 Energy carrier

E-methanol production is technically feasible, with an urgent need of demonstration of industrial scale and market commercialization

Among the potential energy carriers, e-methanol combines multiple advantages, well established transport and bunkering infrastructure, easiness to retrofit many applications to e-methanol and its high energy density (thanks to the CO_2 bound in the product).

HyNetherlands project aims at producing and commercializing 56 kilo tonnes per annum (“ktpa”) e-methanol, which would upscale more than 14 times current pilot demonstrators.

By demonstrating the commercialization of RED2-compliant e-methanol based on renewable Hydrogen and biogenic CO_2, HyNetherlands will also support the decarbonisation of the maritime business, and give a pathway towards Fuel EU maritime initiative and objective of the International Maritime Organization towards reducing CO_2 emissions by 50% by 2050. This would represent 1.5% of global GHG emissions, or 470 Million tons of GHG per year. Several shipping companies have already started converting their engines in their ship fleet to (e-)methanol and HyNL commercial strategy is to enter the market with a premium product (RED2 compliant with biogenic CO2) targeted at low entry price (750-1000 €/t) which will be maintained during scale-up phases

2.2.2.2 CO2 Cycle

Demonstrate circular biogenic CO_2, originating from non-recyclable waste.

Carbon Capture and Utilization (“CCU”) as well as Storage (“CCS”) needs to be upscaled by a factor of minimum 181 to meet EU targets towards GHG reductions. HyNL project will utilize the biogenic share of captured CO_2 from an existing waste-to-energy plant treating non-recyclable waste (fossil share to be stored underground, outside project scope). By doing so, the CO_2 is used to chemically densify the energy content of the renewable-Hydrogen-based energy carrier (i.e. the e-methanol). While avoiding the extraction, production and use of new additional fossil sources, this allows the use of renewable energy for heavy-duty applications (maritime sector, aviation). Instead, circularity is initiated: the e-methanol will be used to propel ships, which will release CO_2 back to the atmosphere. CO_2 from the atmosphere will be trapped in the production process of biomass based goods, which will become wastes when reaching end of life. The non-recyclable share of these wastes will be treated in EEW's waste-to-energy plant, and CC will redirect a share of the CO_2 towards e-methanol production.

2.2.2.3 Engie Eems H2 Roadmap

Demonstrate industrial scale RED2-compliant Hydrogen production with a 100MW electrolysis, and trigger HyNL roadmap towards delivery of affordable Hydrogen and emergence of Hydrogen EU economy.

HyNL will install a 100MW flexible electrolyzer plant, 5 times larger than the state-of-the-art capacity, to produce RED2-compliant renewable-based Hydrogen. But this HyNL Hydrogen plant is also part of an ambitious roadmap, called the ENGIE Hydrogen Roadmap, aiming at deploying 1.9 Giga Watt ("GW") of electrolysis capacity on ENGIE Eems site, producing over 200 ktpa renewable-Hydrogen and avoiding near 3 Million tons of CO_2 by early 2030s.

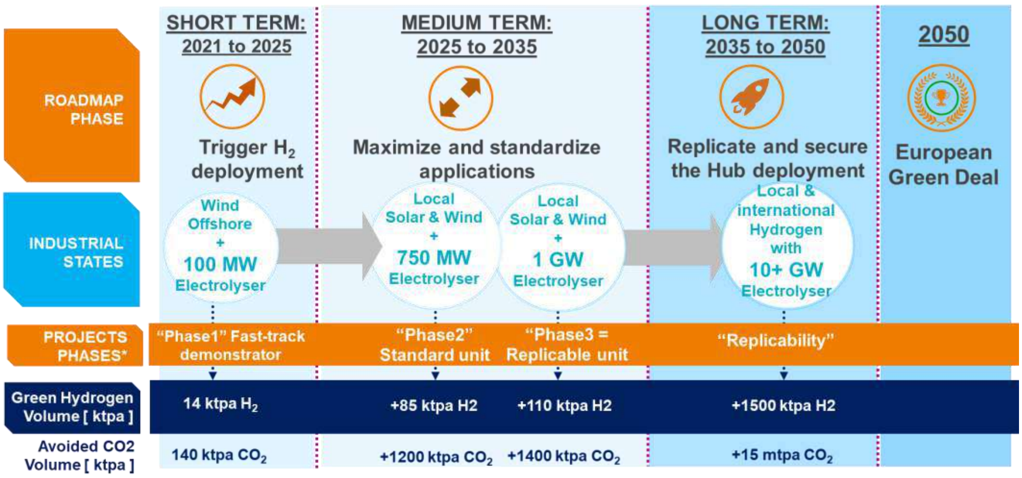


Figure 4: HyNL project is part of the ENGIE Hydrogen Roadmap

The rationale for the need of a roadmap is that dispatchable plants which source intermittent renewable power to produce Hydrogen are not deployed today, and there is no benchmark on the performance of such facilities. The ENGIE Hydrogen roadmap aims at solving resulting technical and financing risks. Every phase prepares the next one, with Phase1 – being the scope of the currently developed – acting as a demonstrator for Phase2. Key objectives of the roadmap are amongst others:

- **Market and financing activation**: this track targets the commercialization of RED2 compliant Hydrogen below 3 EUR/kg Hydrogen cost non subsidized when reaching Phase3. Ultimate goal is to reach 2 EUR/kg on the longer term.

- **Trigger and justify infrastructure deployment**: The different HyNL phases are sized to contribute to justifying the development and deployment of the Hydrogen network across the entire country. Tie in of HyNL Phase1 production facility to the Hydrogen backbone is already designed for volumes corresponding to the 3 HyNL roadmap phases (1.9 GW, or near 300 ktpa Hydrogen – "H_2").
- **Digitalization**: This track aims at delivering a performance model and an energy management system, creating a digital environment (virtual plant) to simulate the integrated HyNL system operation as well as test the best operating strategies before implementation. These innovative tools and approach will support de-risking the first-of-a-kind Hydrogen production facility as well as prepare the tools for its real-time optimized operation.

Key stakeholders have expressed their interest in contributing actively to the Hydrogen financial roadmap and investments.

2.2.2.4 Unique feature: Infrastructure

While not being part of the HyNetherlands investment perimeter, the project will kick start the very first deployment of infrastructure for both transport and storage of renewable power through Hydrogen. Hynetwork[1] and HyStock[2] indicated that HyNetherlands is one of the northern region Hydrogen projects justifying investments in the Northern Backbone[3] infrastructure and salt cavern Hydrogen underground storage respectively. Once this is achieved, it lays the basis for a further infrastructure retrofit and deployment throughout the Netherlands and across European hub, which HyNetherlands longer term roadmap is already developing and justifying on both Hydrogen production and consumption side.

[1] https://www.hynetwork.nl/
[2] https://www.hystock.nl/
[3] https://www.hyway27.nl/en

2.2.3 Specific HyNetherlands objectives

The table below provides a recap on achievements resulting from the HyNetherlands project.

Objectives	Hydrogen production	E-methanol production	Biogenic CO_2 production
Development Phase	Secure access to RED2-compliant renewable energy produced by renewable assets (Power purchase Agreement PPA)	Secure e-methanol offtake and market triggering	Optimize industrial-scale carbon capture of non-recyclable waste treatment plants – technically and commercially
Capacity and upstream process	100 MWe electrolysis installation	Retrofit of an existing fossil-based methanol production facility	Building and interconnecting of two 100ktpa CC units on an existing incinerating unit
Production	Production of ~14,100 tpa of renewable Hydrogen, with at least 70% RED2-compliant Hydrogen	Production of 56,000 tpa of e-methanol	Production of ~77,500 tpa of biogenic CO_2 (for HyNL project)
Systemic operation	Ensure synchronicity of renewable and Hydrogen production, as well as the baseload delivery of RED2-compliant Hydrogen to e-methanol production facility		Ensure synchronicity of biogenic CO2 delivery and e-methanol production facility
Circular material flow and industrial eco-system	Valorisation of >70 ktpa of oxygen in the local Hydrogen industry fabric	Valorisation of 45 GWh/y of heat in the form of steam in the local industrial estate	Recycling of 77,500 tpa biogenic CO_2 from incineration of non-recyclable wastes
Objectives 2y after COD	Potentially first filling of 2 salt caverns cushion gas.		

Table 1: Project objectives HyNetherlands

2.3 Key messages

A paragraph covering some key messages from the deliverables described further in the document.

- Project HyNetherlands is confirmed to be technically feasible.
- To reach financial feasibility, the project has applications pending from several grantors
- As a starting point, REDII will be implemented, taking into account transitional measures allowed by the EU, where necessary and relevant.
- The production of Hydrogen is located on the ENGIE site in Eemshaven, and will make partial use of existing technical installations and facilities of the power plant.

- The required environmental permit is currently processed by the authorities of the Environmental Services Groningen and expected to be granted by the end of 2022.
- The Province of Groningen has decided that it is not required for the HyNetherlands project to conduct an Environmental Impact Assessment (EIA = M.e.r.)
- HyNetherlands contracts the required electricity from renewable sources.
- The produced renewable Hydrogen is mainly transported to the customer by the pipeline of HyNetwork Services (Gasunie) and partly by trailers to the mobility sector.
- OCI (BioMCN) uses the Hydrogen to produce e-methanol and thus avoids the use of natural gas and the emission of carbon dioxide in their process.
- EEW provides the required biogenic carbon dioxide for the production of e-methanol by implementing CCU at its facility in Delfzijl.
- Port authority Groningen Seaports provides the pipeline to transport carbon dioxide from EEW to OCI.
- Tendering process started for EPC 100MW Hydrogen production facility based on a technology agnostic approach through a Minimum Functional Specification. The selection process should be concluded by October 2022.
- The Hydrogen production facility 100MW is the first step in an approach to add 750MW by 2030 and another 1GW in the early 2030's.
- Knowledge sharing is integrated in the project approach.

As reported on April 20th 2022 in 'Answers to the outstanding request for additional information HEAVENN , periodic reporting 2021 (request dated 12-04-2022)' ENGIE explained the change of plans, meaning not to execute a complete FEED-study by definition. It is not obvious to conclude in this evolving market which current available technology, or technology variant, is best fit for the targeted performance. Therefore ENGIE decided to adapt a technology agnostic approach, indicating that ENGIE does not define by itself or by a consultant the best technical solution for its project, but it challenges the potential suppliers to present their best offer fit for purpose with the latest technological and configuration insights.

The basic and detailed engineering will not be executed in a classical FEED-phase, but is part of the scope of the EPC contractor. To allow a fair competition, and to test the EPC market whether the procurement strategy considered for this first stage (which eventually will be replicated in the scale up to GW scale) is viable, a Minimum Functional Specification (MFS) has been developed. To produce this document several studies had to be conducted, consultations with different parties and results from previous studies had to be integrated in the Minimal Functional Specifications ("MFS"). This is a time consuming iterative process involving several experts and different disciplines (environmental, civil, process, safety, electrical, mechanical,…) providing ENGIE the basis for upscaling the production capacity of renewable Hydrogen to firstly 100MW in a growth towards GW-scale.

The overall purpose of the HyNetherlands knowledge sharing is to promote and accelerate the large-scale development of competitive and innovative low-carbon technologies throughout Europe and to create Hydrogen valleys, ensuring their widespread acceptance and adoption by all stakeholders. This sets the objectives, key messages, (key) stakeholders, social media plan, communications plan and indicators for monitoring and follow up of activities to share and disseminate information about the project.
We will pro-actively onboard our stakeholders into the project and show them topics like environmental, technical, and economical benefits for them whatever their level (offtakers, politics, environmental groups, local residents and others). This knowledge sharing plan contributes to the stakeholder engagement.

3 Deliverables WP6

3.1 Solution Design

3.1.1 Technical configuration

The HyNetherlands project (HyNL) aims at developing, building and operating an innovative first in kind 100MW fully flexible electrolyzer plant, .
The project has been designed to act as a resilient fast-track development project, by combining (i) resilience to the stringent criteria which might be imposed by RED2 policy, (ii) resilience to Hydrogen underground storage infrastructure possible delay in development, through linepack storage in the Hydrogen backbone pipeline and (iii) crucial innovations which are present in HyNL project to address key challenges when scaling up the project 8 times by 2030 (mainly relating to intermittency and bankability).

It is not obvious in this evolving market which current available technology, or technology variant, is best fit for the targeted performance. Therefore ENGIE adapted a technology agnostic approach. This indicates that ENGIE does not define by itself or by a consultant the best technical solution for its project, but challenges the potential suppliers to present their best offer fit for purpose with the latest technological insights. This means that a detailed engineering will not be executed upfront, but will be part of the scope of the contractor. To allow a fair competition, and to test the EPC market whether the procurement strategy considered for this first stage (which eventually will be replicated in the scale up to GW scale) is viable, a Minimum Functional Specification (MFS) has been developed. To produce this document several studies had to be conducted, consultations with different parties and results from previous studies had to be integrated in the MFS. This is a time consuming iterative process involving several experts and different disciplines (environmental, civil, process, safety, electrical, mechanical,…) providing ENGIE the basis for upscaling the production capacity of renewable Hydrogen to firstly 100MW in a growth towards GW-scale.

The ENGIE Hydrogen plant will be able to deliver up to 20,000 Normal cubic meter per hour ("Nm_3/h") of Hydrogen over the project lifetime using a 100 MW electrolyzer anticipated to be powered by offshore wind turbines. Two electrolysis technologies, i.e. pressurized Alkaline electrolysis ("AE") or a Polymer Electrolyte Membrane ("PEM"), are considered as good candidates to achieve the scale up from the current 20 MW mature technologies up to the first 100 MW electrolyzer as well as for allowing a fully flexible operation mode capable of following the intermittent wind supply profile.

HyNL will produce and commercialize renewable-based e-methanol and Hydrogen. The overall round trip efficiency for the whole wind to e-methanol energy conversion is 61%. The ENGIE Hydrogen plant will be able to deliver up to 14.1 ktpa (20,000 Nm3/h) of 70% RED2 compliant Hydrogen over the project lifetime using a 100 MW electrolyzer powered by a wind capacity of 200 MW provided by offshore wind turbines

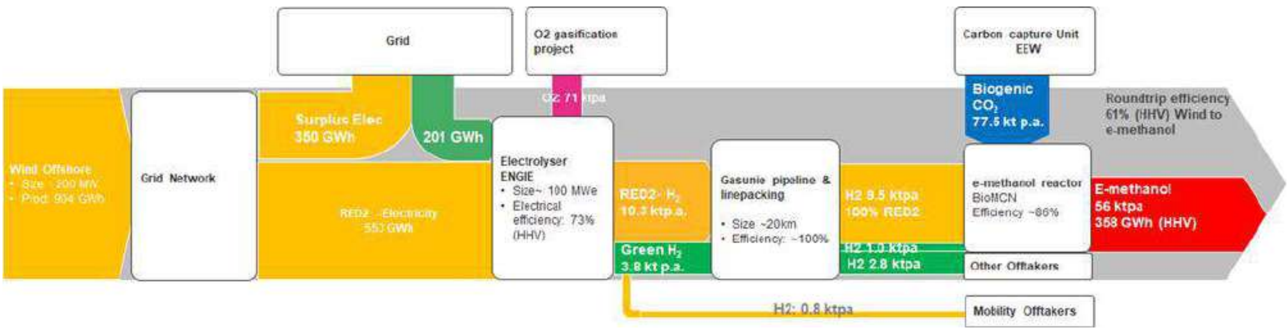


Figure 5: Volume representations of principal streams of complete HyNL project.

The electrolysis plant will consist of a High Voltage/Low Voltage transformer, Alternating Current/Direct Current ("AC/DC") rectifiers, electrolyzer stacks, an electrolyte system depending on the considered electrolyzer technology, pumps, heat exchanger, compression and purification system, and Hydrogen/oxygen offtake infrastructure. Most components will be delivered as a skid to be installed and interconnected with the other processes skids and installations already present on site, the aim being, to benefit, as much as possible, from existing infrastructures (demin water, high voltage system, seawater cooling) and maximize fabrication in well controlled factories. Finally, the plant will be controlled using a SCADA supervision system, which will allow to visualize the status of all equipment connected to the plant and to control and operate them. On top of the SCADA system, an Energy Management System will be developed to optimally steer the complete supply chain from power supply to Hydrogen delivery towards a minimal levelized cost, leveraging its flexibilities while accounting for the renewable forecasts uncertainties.

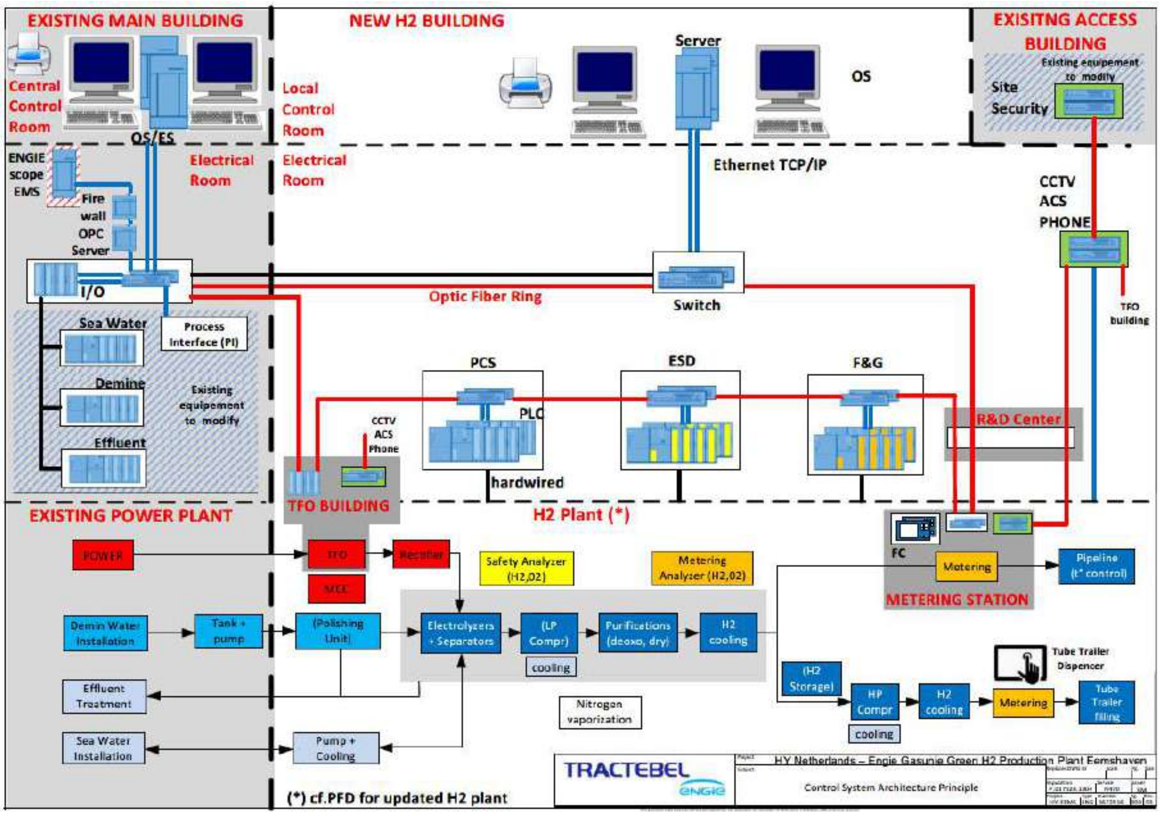


Figure 6: ENGIE H_2 Plant Control System Architecture

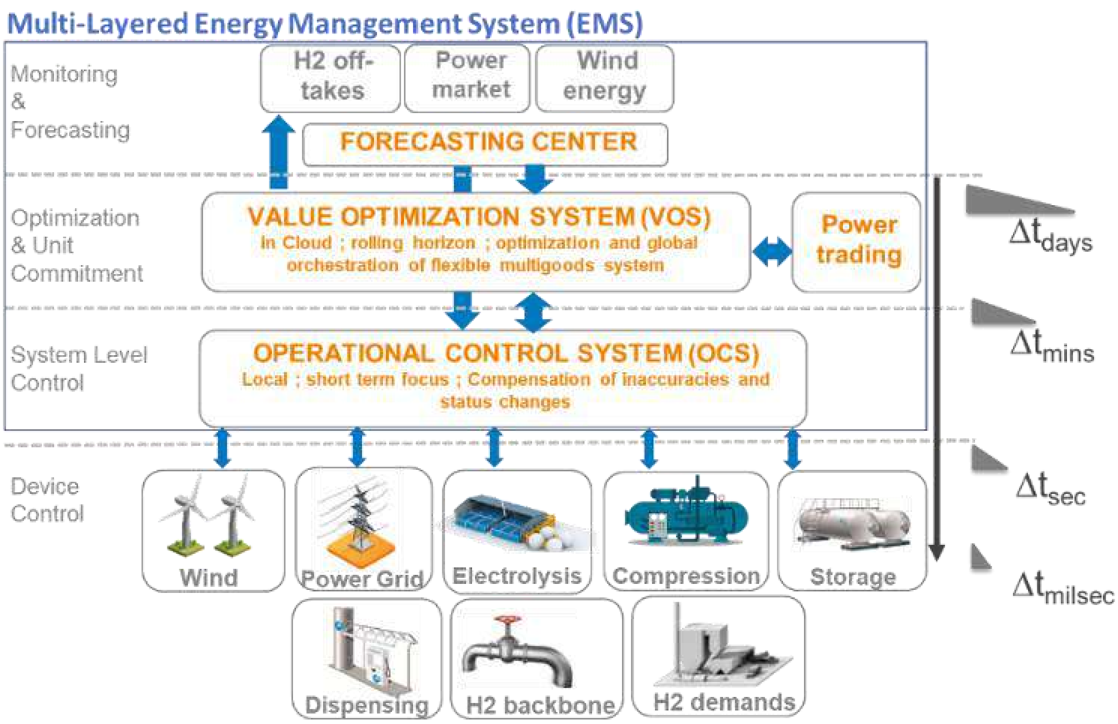


Figure 7: Model Energy Management System (EMS)

3.1.1.1 H_2-Plant general description

The H_2 -Plant consists of a Hydrogen production and delivery system. The H_2-Plantis based on the water electrolysis principle, receiving the necessary sources(water, compressed air, cooling, ...) and intermittent electrical power supply through the adjacent ENGIE-EEMS-PP grid connection, delivering to a Hydrogen grid, managed by the Hydrogen Pipeline TSO in the Netherlands, and high-pressure Hydrogen transport trailers (tubes trailers/gas cylinder containers).The H2-Plant shall have for its entire life a 20000 Nm³/h guaranteed capacity of produced Hydrogen. Total Hydrogen produced flow will be distributed as follow:

- Maximum capacity shall be available to transport pipeline for the Industry sector
- Up to 10% of the maximum capacity shall be available to trailers for the Mobility sector.

The main controlling of the H2-Plant will be done from the existing Control room of the ENGIE-EEMS-PP.

3.1.1.2 Regulations, standards, quality requirements

The Contractor shall demonstrate convincingly that (i) the engineering, design, manufacturing, construction and testing of all equipment, facilities, components and systems which form part of the H_2-Plant shall be in accordance with the local regulations/ Law, (ii) internationally recognized standards and codes and (iii) the existing Power Plant standards and rules as set out in the invitation to tender.

In the event of any conflict in the standards, the hierarchy of standards shall be as follows, with the standards occurring first in the list taking precedence over any standards later in the list:

(I) Statutory regulations of the country of installation
(II) EU directives and regulations mentioned here after
(III) Regional and Local rules
(IV) Standards and codes named in the Specifications
(V) International Standards and codes
(VI) Other standards approved by the ENGIE

The latest editions in force of the standards, codes, regulations, recommendations and directives shall apply for the design, construction, testing, commissioning, operation and maintenance of the facility.

Requirements of the environmental permit, of the environmental impact assessment and requirements of the Netherlands labor code will be taken into account for the design of installations. As a standard approach the contractor shall use, and impose to its subcontractors to use, approved design codes. When design codes and standards are indicated in this specification they shall apply. In case of contradiction, the contractor shall consult with the ENGIE on the approach to be adopted. When no standard is indicated, the contractor shall use a design code that is logical in the entire set of design codes used for the project. Manufacturer standards are in principle not accepted. Any deviation from this shall be clearly justified and demonstrated to the ENGIE for approval.

3.1.2 FEED H_2-production <pragmatic approach>

The suppliers market of electrolysis stacks is a technological evolving environment confronted with an extreme rising demand for offers and configurations for new initiatives. It is not obvious at this stage which current available technology, or technology-variant, is best fit for the targeted state-of-the-art performance.
In order to maximise ENGIE's chances of receiving the best proposal for its initiative to produce Hydrogen in Eemshaven with a plant performance that matches its ambition, a so-called technology agnostic approach was applied. This approach implicates that the configuration of the new plant is not pre-defined by ENGIE nor a engineering consultant through the process of a FEED (by definition). The potential suppliers are challenged to present their best offer fit for purpose with their latest technological insights, all based on a Minimum Technical Specification that has been developed by ENGIE with the support of a technical consultant, namely Tractebel Engineering. This approach leaves the supplier to develop or use it already developed technological solution, whether this will be e.g. pressurized alkaline electrolysis (AE) or polymer electrolyte membrane electrolysis (PEM) as long as the installation applies to the required performance prescribed by ENGIE in the Minimum Functional Specification document. In this way ENGIE will be able to evaluate each EPC bidder’s most optimal solution by making a full lifecycle cost analysis as well as to technically evaluate the proposed solution maturity, reliability and operability.
The targeted procurement EPC-approach includes the complete Hydrogen production facility, the defined interfaces with the existing ENGIE Power Plant, the on-site storage, a testing area with relevant facilities, a tube trailer high pressure loading station and a metering station with the tie-in to the backbone of HyNetwork Services.

3.1.3 Electrolysis configuration

Until firm offers allowing to assess in detail the Total Cost of Ownership, both pressurized Alkaline Electrolysis (AE) or Polymer Electrolyte Membrane electrolysis (PEM) technologies are considered. A typical PFD illustrating the setup of an electrolysis facility is provided in the figure below, this figure was obtained by NEL when supporting the feasibility study in 2019, this PFD as well as those provided by other suppliers participating to the feasibility study, led to the ENGIE Hydrogen conceptual plant PFD.

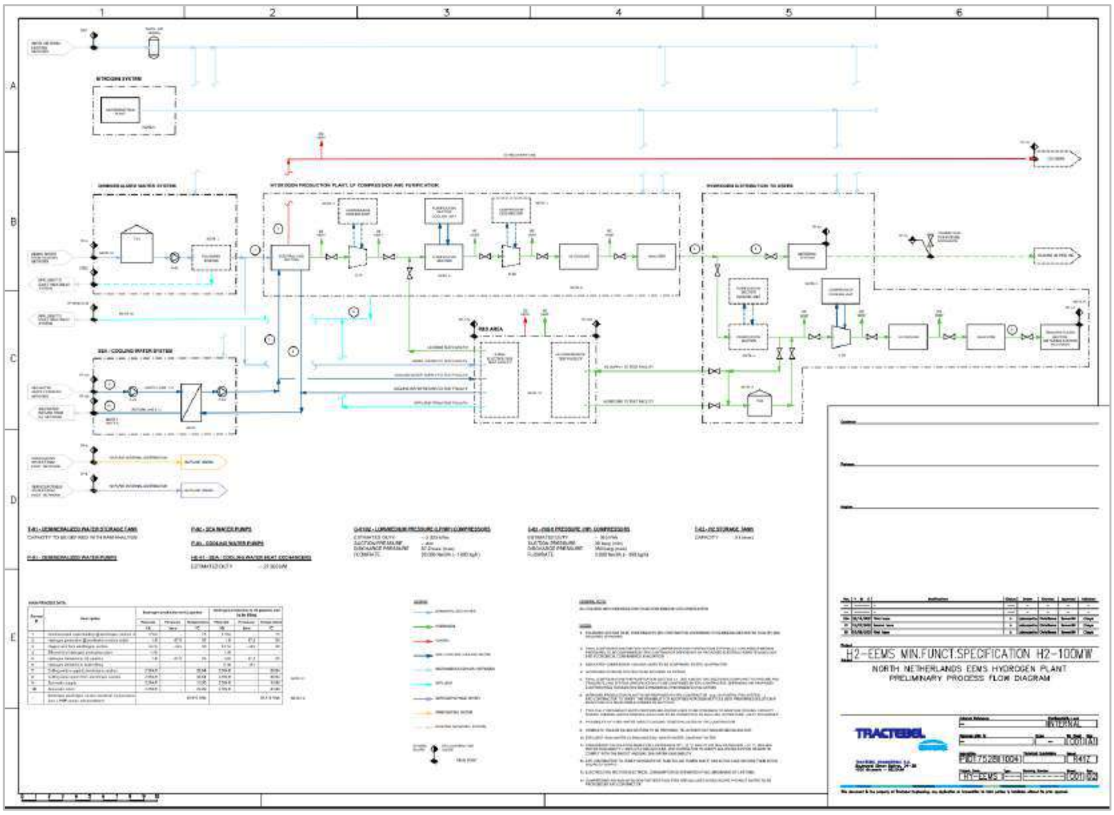


Figure 8: PFD HyNetherlands 100MW Hydrogen production

As energy cost in the western Europe geography accounts for approximately 60-70% of the levelized cost of Hydrogen, this means that the guaranteed efficiency of the electrolyzer will play an essential role in the selection criteria. Based on inputs from the European electrolyzer suppliers for the EPC selection (ongoing), an electrolyzer efficiency of 52.7kWh/kg has been assumed in the business plan, including the BOP this gives 53.7 kWh/kg for the entire H_2 plant (including the compressors, auxiliaries and water pumps). These figures will need to be updated after the technology is confirmed.

The electrolysis system will consist of the HV/LV transformers, ACDC rectifiers, electrolyzer stacks, the electrolyte system (KOH 25-30 %wt.) if any, pumps, heat exchangers, compression and purification system. Most components will be delivered as a skid, to be installed and interconnected with the other skids on-site, and with the other installations on site.

33/6kV transformers convert the electricity in high voltage alternative current into a low voltage alternative current suitable for the rectifiers. The rectifiers convert the alternative current into a direct current suitable for the electrolyzers stacks. The electrolyzers stacks convert with the supplied electricity the demineralised water to Hydrogen, oxygen and heat via the following electro-chemical reaction as can be seen in the figure shown; 2 H_2O + electricity → 2 H_2 + O_2 + heat.

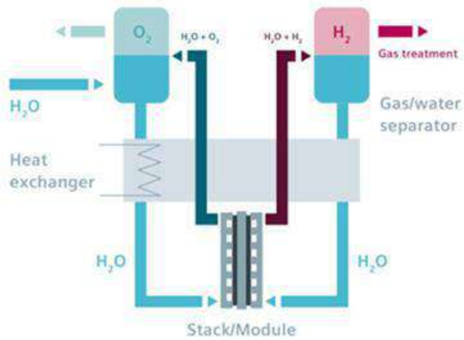


Figure 9: Working principle of a water electrolyzer (Source: Siemens)

The balance of plant has the following general process functionalities, KOH in brackets since not yet decided whether AE or PEM technology will be used:

- Feed the demineralised water (+KOH) to the stacks
- Evacuate the Hydrogen / water (+ KOH) mixture from the stacks
- Separate the Hydrogen from the Hydrogen / water (+KOH) mixture
- Cool the Hydrogen / water (+KOH) mixture
- Evacuate the oxygen / water (+KOH) mixture from the stacks
- Separate the oxygen from the oxygen / water (+KOH) mixture
- Cool the oxygen / water (+KOH) mixture

The purification equipment to purify the Hydrogen exiting the electrolyzer, consists generally of an oxygen removal - de-oxo - and a dryer. The oxygen removal is a catalytic bed, reducing the remaining O_2 present in the Hydrogen to < 5 ppm. The drying unit is based on Thermal Swing Adsorption reducing the remaining H_2O < 5 ppm. For Alkaline Electrolysis a scrubber is added to remove the electrolyte KOH before the de-oxo and the dryer.

These functionalities may be differently arranged depending on the selected electrolysis technology and the supplier. The exact number of the different components and the complexity of the electrolysis system will also depend on the chosen supplier. All preliminary OEM technical proposals were assessed during the feasibility study and were found to be feasible for implementation in this project.

The alkaline technology generally requires more components than the PEM technology; for example, the PEM technology doesn't require scrubbers because there is no electrolyte (KOH), only demineralised water.

For the present 100 MW Hydrogen plant following info was obtained from the 2019 Feasibility Study:

- NEL (alkaline 0.02 barg) has proposed 11 transformers, 22 rectifiers, 42 electrolyzers and 21 balances of plant
- ThyssenKrupp (alkaline 0.3 barg) has proposed 5 transformers, 5 rectifiers, 10 electrolyzers and 10 balances of plant
- John Cockerill (alkaline 16 barg110) has proposed 16 transformers, 16 rectifiers, 16 electrolyzers and 16 balances of plant
- Siemens (PEM 0.15 barg) has proposed 12 transformers, 24 rectifiers, 6 electrolyzers and 6 balances of plant
- ITM (PEM 20Bar) has proposed 5 transformers, 5 rectifiers 11 electrolyzers and 5 balances of plant.
- McPhy (alkaline 30 barg) has proposed 5 transformers, 5 rectifiers, 5 electrolyzers and 5 balances of plant.

Since them some of these parameters, such as pressure increase have been updated verbally, a firm update is expected after summer 2022.

The operating conditions of the electrolyzer stacks depend on the supplier, following operational range summarizes obtained inputs:

- Outlet pressure: 0.02 to 30 barg (before compression),
- Temperature: 55 to 85 °C,
- Hydrogen purity: 99.8 to 99.9 %vol on a dry basis (the remaining impurity being mainly oxygen, but also possibly some nitrogen and some KOH),
- Oxygen purity: 99.4 to 99.5 %vol on a dry basis, making it suitable for various applications.

3.1.4 Civil Design

The activities pertaining to the part "civil works" of the Contract are listed here below. The civil works activities are nevertheless not necessarily limited to this list.
The Civil Works are among others:

- All necessary engineering activities for civil works including preliminary design, design for construction, final design and as built documents

- Site surveys including topographical survey, survey of possible existing underground networks or obstacles and soil and geotechnical complementary investigations, if necessary
- Site preparation including, among others, removal of vegetation, removal of existing underground networks and obstacles if necessary, removal of arable earth, levelling of the ground surface
- Temporary site facilities including all necessary roads, accesses, gates and car parks, the necessary rainwater drainage, the networks for temporary utilities and the temporary site bungalows
- Inside of the Site all necessary earthworks for foundations, buildings, pipes and cables trenches, underground networks, roads, hard standings, walkways and access roads
- Deep and shallow foundations for all equipment defined in the other parts of the Contract.
- All buildings defined in the “General Layout” drawing including foundations, superstructures, cladding, roofing, building finishes and building techniques.
- Compounds for indoor transformers
- All necessary underground culverts and ducts for piping and cabling
- All necessary hard standing areas and access roads to equipment or buildings
- Rainwater drainage and wastewater sewage systems
- Landscaping and site finishing.
- Construction file (drawings, sample test results, technical data, ...)

3.1.5 Hydrogen Transport and Storage

The tie-in to the Hynetwork backbone will be governed by the Hydrogen Transport Agreement and the Hydrogen Entry Connection Agreement. Hynetwork has started pre-consultation on the contractual framework for Hydrogen transport in February 2022 with a number of potential counter-parties. This pre-consultation is taking place with advanced Hydrogen project developers, of which HyNetherlands is considered to be one. Hynetwork considered the feedback from this consultation and organized a wider industry consultation round in Q2 2022 after which the standard agreements (applicable to each party that connects to the backbone) are being endorsed by the authorities.

Specific conditions applicable to HyNL connection, transport and line packing needs, are currently being developed by Hynetwork via several workshops with the HyNL teams, in parallel to the development of the mentioned agreements. On this basis, the agreed timeline with Hynetwork is to reach a Conditional Hydrogen Transport Agreement by end of 2022. The conditional character of the agreement is bound to subsidy and permitting securement of both parties. In case of delays, the deadline can be extended to June 2023 without impact on the HyNL project schedule, while it is not the intention to activate these timing contingencies. The above activities are resulting from a Letter of Intent that has been signed with Hynetwork in 2021.

Hynetwork confirmed that an interconnection (‘tie-in’) with the electrolyzer plant will happen at the ENGIE site boundary. These connection works will be performed by Hynetwork. The Hydrogen metering station, to be owned by ENGIE and located at the ENGIE Eems site, will be built by the EPC Contractor as per Hynetwork required standards and protocols and it will be operated by ENGIE, a signal exchange with Hynetwork control centre will need to be established. As the regulatory framework is still under development, these standards and protocols have not yet been finalised by Hynetwork, but several exchanges and (ongoing) workshops between the parties have resulted in a first concept that is translated in the EPC Minimum Functional Specifications , used for tendering. Conversations are currently ongoing about the role the ENGIE Hydrogen plant can play in the start-up of the backbone phase I, as the commissioning of this system will require commissioning Hydrogen. In case there is a role for ENGIE in this activity it will be reflected in the contractual agreement with Hynetwork Services unless the Gasunie subsidiary will tender the activity at a later stage.

A Letter of Intent has been signed with HyStock to cooperate towards their respective (C)FID on their respective Hydrogen underground salt cavern storage projects and to help each other to their best abilities in order that the (C)FIDs can be taken in an affirmative manner. The contractual and technical discussions will continue to take place in 2022, progress will be made depending on the minimum required storage capacity of the cavern being booked. The ENGIE Hydrogen plant project has mitigated impact from potential delays of the cavern to become available by securing 25 ton linepack capacity in the Hynetwork backbone until the cavern storage can be used.

3.1.6 Location Hydrogen production

The HyNetherlands Hydrogen production is projected at the ENGIE site of the Eems Power Plant EC3-7. ENGIE provides the required land for the project, as well as logistic and technical benefits of already existing and operational installations. E.g. the required deminwater for electrolysis can be provided by the current existing demin-plant by using the spare capacity avoiding additional investment. Other facilities that are provided concern HV grid connection, sea cooling water, compressed air, firefighting system, effluent system and the central controlroom of the power plant.

- The future expansion of the Hydrogen production to GW-scale is also projected at the same site of ENGIE.

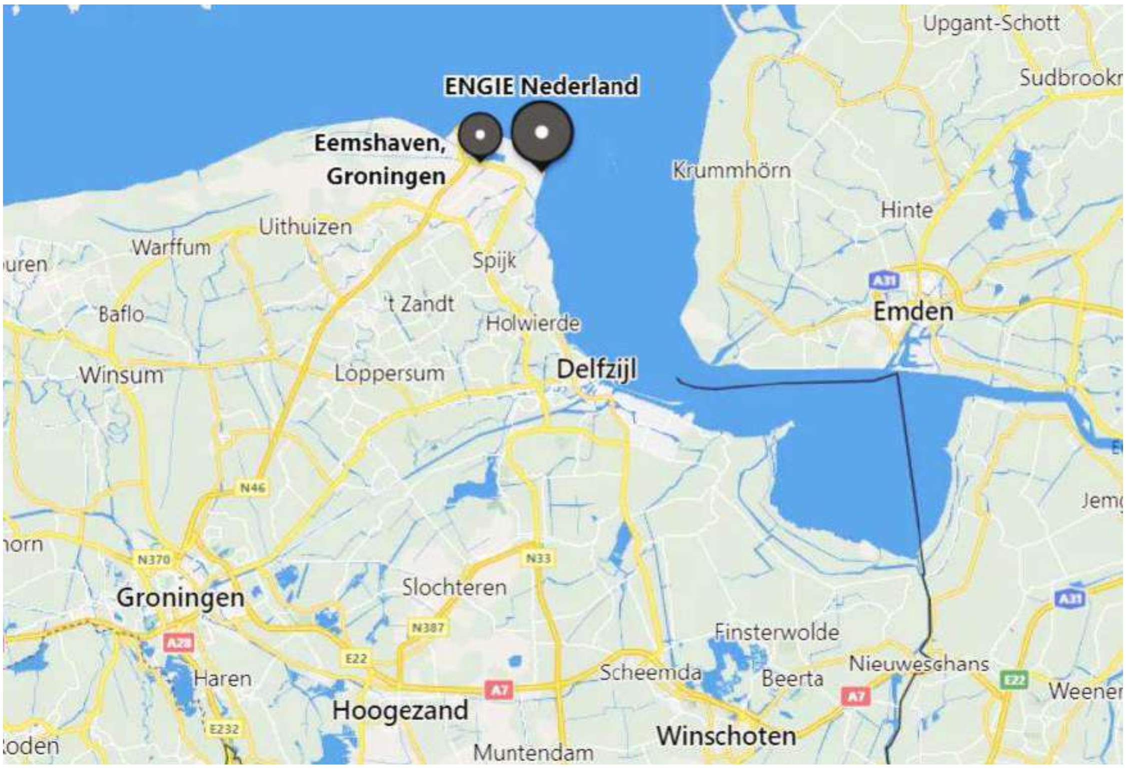


Figure 10: Location ENGIE site Eemshaven

Figure 11: Overview ENGIE site Eemshaven

3.1.7 HV grid-connection 380kV

Unit EC7 of the ENGIE-EEMS-PP is connected to the TenneT (Dutch electrical grid operator) Eemshaven substation via a 380 kV cable and the 440 MVA - 380 / 23 kV transformer. The power supply coming from the ENGIE-EEMS-PP to the H_2-Plant will be via a 33 kV cable connection. The 33 kV power is to be transformed from the 23 kV IPB of the ENGIE-EEMSPP unit EC7 via a new 23 / 33 kV transformer.

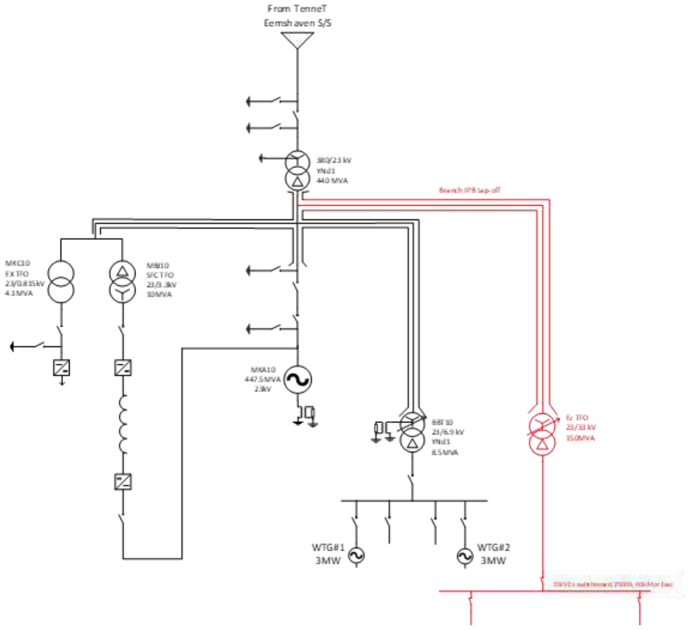


Figure 12: Grid-connection via EC7

To connect the Hydrogen plant to the existing Unit 7 Power Evacuation line, the system has to be connected on the IPB between the Turbine Generator and the associated Step-up Transformer i.e. a tap-off from the main IPBD.

The harmonics caused by the Hydrogen plant are to be limited according requirements in the executed study by ENGIE Laborelec. This report shows the results of the harmonic load flow that assesses the maximum limit of harmonic pollution that can be injected to the point of common coupling at the secondary (23 kV) side of the step-up transformer of unit 7, in compliancy with the grid codes and

existing standards. In general the EN 50160 and the Dutch grid code are to be followed. Specifically for the power transformers also standard IEC-60076-1 is to be followed. Furthermore, the project has to obtain a design approval by the National Electricity provider of their design, according to the European directives and IEC 61000-3-6.

3.1.8 Water, effluent and air

3.1.8.1 Cooling water (seawater)

Main function of the sea water / cooling water system consists in the proper dissipation of the heat rejected during the electrolysis process, including related auxiliaries, such as purification section and compressors. Sea water shall be used for cooling an internal closed cooling water circuit (CCWC). For this purpose, heat exchanger(s) shall be used to separate the sea water side and the CCWC. Alternatively, the contractor shall verify the possibility to directly feed the H2-plant with sea water, without the use separation heat exchanger: in any case two lines sized for the full cooling capacity shall be foreseen to manage the ENGIE EEMS-PP thermal shock (cleaning of the system) periods.

Surface water of the Eemshaven estuary is taken in as cooling water for the use of the ENGIE-EEMS-PP and is discharged again in the estuary. The water of the Eemshaven estuary is brackish. The existing sea water intake, screens and pumps of the existing ENGIE-EEMSPP will be used to feed the cooling water system of the new H_2-Plant.

The average temperature of the cooling water is assumed to be 11.88°C (year average according to measurements of the Ministry of Infrastructuur en Waterstaat). Min of -1.5°C and Max of 24°C is considered (based on data received from ENGIE-EEMS-PP).

3.1.8.2 Demineralised water

Demin water is made available by the existing ENGIE-EEMS-PP to serve the H_2-Plant's needs for demineralised water. The demineralised water will be supplied at the battery limit of the H2-Plant with the characteristics required by the electrolysis technology. Basically the existing demin-production requires no additional treatment and the available capacity of filtration is sufficient.

3.1.8.3 Effluent system

Main function of the effluent system is to collect and deliver effluents from the Hydrogen plant to the atmosphere (i.e., H_2, O_2 and N_2, venting) or to the existing treatment system. In principles the nature of the Hydrogen Generation H2-Plant effluents is anticipated to be:

Hydrogen and Nitrogen, when stopping the plant, through the purges/venting of the process;

- Oxygen, should no valorisation be found for this by-product;
- Water from the process;
- Rain/storm waters;
- Electrolytes (e.g. KOH).

On the ENGIE-EEMS-PP-site there is a sewage system discharging treated wastewater to the Eemshaven estuary. Rain and storm water is collected in a separate system and discharged to the Eemshaven estuary. Any other effluents are collected in enclosed tanks and taken away by contractors that have a permit to.

3.1.8.4 Firefighting system

On the site there is a firefighting water system with hydrants around the existing units. Water from the firefighting water tank (2 x 250 m^3) is taken in by a 5 m^3/h jockey-pump and 90m^3/h main pump and distributed around the ENGIE-EEMSPP buildings through a DN150 buried water pipe (operating at 8 barg).

3.1.8.5 Instrument air

Main function of instrument air system consists in ensuring operation of pneumatic control loops, dedicated instruments of the technology, control valves and pneumatic fail-safe valves contemplated in the Project.
Instrument air from the existing ENGIE-EEMS-PP plant will be used by the H_2-Plant. The air quality is standard industrial compressed instrument air, clean, dry, filtered, without oil, according to ISO8573-1:2010 specs 1-2-0

3.1.8.6 Compression and storage H_2 and O_2

Depending on the electrolyzer operating pressure, the Hydrogen is either collected to the downstream low pressure compression (if needed) or directly to the purification unit. Since Hynetwork' backbone operates at a pressure range between 30-50barg, the installation of reciprocating Hydrogen compressors is needed, 2x100% or 3x50% capacity is considered to ensure reliability of the production process. During 2021 workshops, Hynetwork informed that the operating pressure of the backbone might be increased in the future to 67barg, the current design pressure of the existing part of their natural gas to-be-repurposed network. To anticipate this change, that may only occur after 10 year of operation, the project foresees that the design of equipment and piping downstream the compressors is designed for an injection pressure of 67barg. For the initial operation period it is foreseen to design the compressor for an operating pressure of 30-50barg and make adjustments will be made if it would be decided to increase the pressure in the future.
A specific Hydrogen compressor technical specification has been developed by ENGIE internally, the document is built based on internal expertise, feedback obtained via various forums participated to and information from the market. The specification forms part of the MFS to be complied with by the EPC Contractor.

At the outlet of purification (if needed) and after the analyser, Hydrogen is sent to the gas grid by means of a main pipeline. On this pipeline a branch pipeline is present to supply H_2 to the trailer filling section. To adjust produced Hydrogen pressure and temperature to user's requirements, two compression and Hydrogen cooling sections are foreseen:

- The LP compression and cooling section, located before the purification and featuring 50 barg as max operating pressure (being 67,2 barg the design pressure to be considered for the piping design)

- The HP compression and cooling section, located on the detachment line and featuring 380 barg high pressure trailer filing level.

Cooling for compressors, purification process and Hydrogen can be realized with sea water or dedicated cooling systems. Hydrogen temperature at pipeline delivery point shall be compliant with Hydrogen Pipeline TSO specification; Hydrogen temperature for trailer filling shall be compliant with EPC Contractor and related safety standards.

H2 storage on and off site shall be possible through:

- A 25t line packing in the Hydrogen Backbone provided by TSO HyNetwork Services (HNS), until a underground storage of HyStock becomes available and connected to the backbone (out of scope ENGIE). The characteristics of this line packing is subject of deliberations between ENGIE and HNS.
- An on-site 5t storage.

The HyNetherlands project includes options to provide Oxygen to external customers. The required tie-ins are included in the technical configuration up to the metering station.

3.1.9 Detailed breakdown of O&M

The control system of the Hydrogen production plant is designed to allow fully automated start, stop and flexible operations within the required design conditions of the plant in all circumstances. Operators should be able to easily assess start- or stop sequences interruptions and manually interfere to the extent process safety is not jeopardized. During normal operations the dispatch of the Hydrogen plant will be done by the Energy Management System with which the PCS system will exchange all relevant signals. In case the EMS system is not available, the plant shall be operated via manual dispatch signals originated by the Operator in the control room. For the sake of clarity, the EMS shall by no means be considered to handle any process safety supervision or control function, these are all to be integrated within the PCS.

ENGIE wishes to assess through the EMS, the short and long term operational impact of intermittent (renewable) power supply on the Hydrogen production plant. The EPC Contractors are therefore requested to present to ENGIE, for approval, an operation philosophy that ensures at least one and the same electrolyser including its upstream/downstream associated auxiliaries to experience maximum impact from the intermittent dispatch signals that will be obtained from the EMS. The remaining part of the plant shall cope with the available (possible intermittent) power in the most efficient way. The ENGIE shall have the possibility to switch from this strategy (research mode) to the most suitable operation mode defined by the EPC and vice versa without any physical intervention inside the plant.

3.1.10 Green field and brown field

The 100MW Hydrogen production of HyNetherlands is projected at the site of the ENGIE Eems Power Plant. The configuration of the project is split in 2 sections; a green field part and a brown field part.

The main part of the ENGIE H_2 plant will be green field development, meaning a newly developed and build Hydrogen producing facility. However as indicated before it is envisaged for the project to (re-)utilize as much as possible existing infrastructure, the most important interfaces are listed here below:

- The power plant chemistry and operations teams have confirmed that the existing demin water production plant can meet the consumption for electrolysis in both volume and specification. This includes continuing water supply to the existing installations. No additional investment is required.
- Instead of establishing a new high voltage connection to the substation of the national grid, the Hydrogen plant will be connected to the internal High Voltage system of one of the existing power plant units, EC7. This requires an interface connection to this system and integration of the protections. An in depth assessment made during the 2019 feasibility study confirmed this approach is possible.
- The power plant is provided with a sea cooling water system. The present capacity enables providing the required cooling capacity of the Hydrogen production without affecting the performance of the powerplant or interfering with currently applicable environmental permits.
- The operations of the Hydrogen plant will be integrated in the existing central control room of the power plant
- Site access, the electrolyzer plant will be accessible through the main gate of the existing powerplant, except for the tube trailer truck that will be able to access via a dedicated and automated new access. The set up assures that the truck drivers will not be able to access any other area than the loading zone

3.1.11 Metering station Hydrogen

Hynetwork confirmed that an interconnection with the electrolyzer plant will be situated at the ENGIE site boundary. These connection works will be performed by Hynetwork. The Hydrogen metering station, to be owned by ENGIE and located at the ENGIE Eems site, will be built by the EPC Contractor as per Hynetwork required standards and protocols and it will be operated by ENGIE, and signal exchange with Hynetwork control center will be established. As the regulatory framework is still under development, these standards and protocols have not yet been finalized by Hynetwork, however several exchanges and workshops between the parties have resulted in a first concept that is translated in the EPC Minimum Functional Specifications (MFS), used for tendering. The start-up of the Hydrogen backbone in phase I, including the first-filling with Hydrogen, is in the scope of HyNetwork Services.

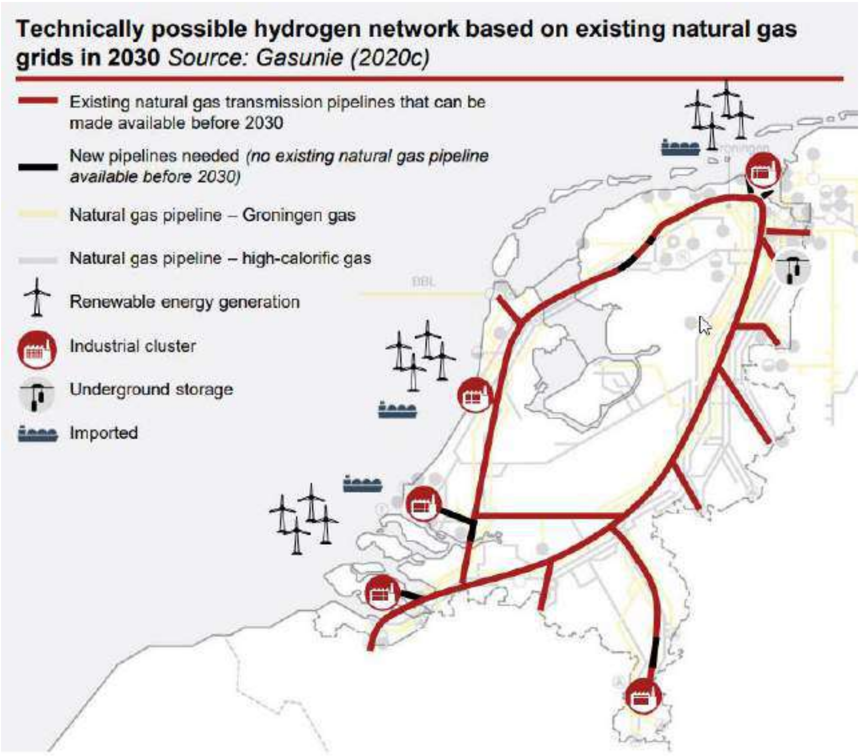


Figure 14: Hydrogen Network Gasunie (source: website HyyWay27)

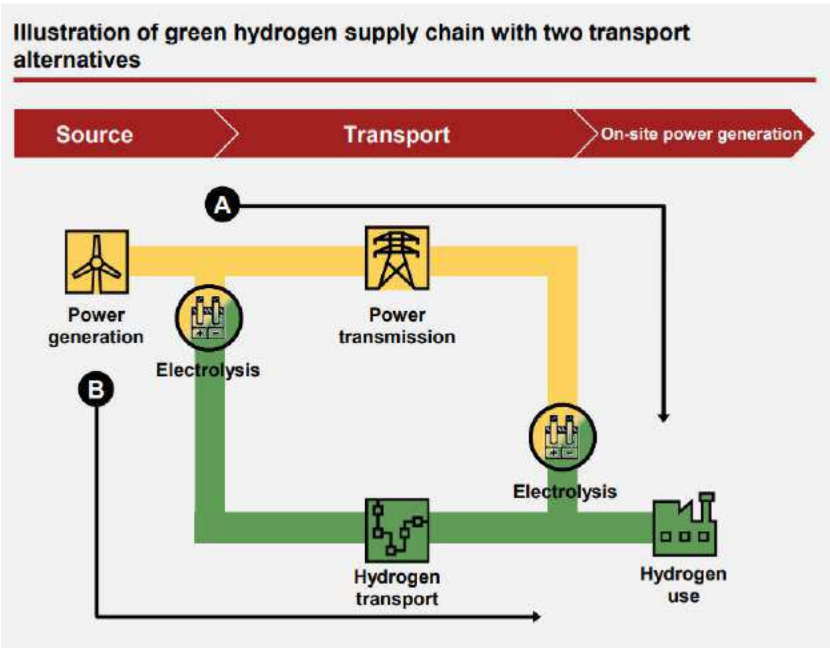


Figure 15: Renewable Hydrogen supply chain (source: website HyyWay27)

3.1.12 Lay-out Green Field

ENGIE has constructed a preliminary design of the green field part of the project. This newly to establish part of the project concerns the complete Hydrogen production system, filtering, buffering, compression and truck-loading bays. And also includes a limited Hydrogen storage, a testing area and the emergency power system.

The layout shall be optimized by the EPC-contractor to the requirement of their best offered configuration and considering the properties and orientation of the plot, the site conditions, the site accesses, the locations of the various Interface Points and the impact from, and on, the surroundings.

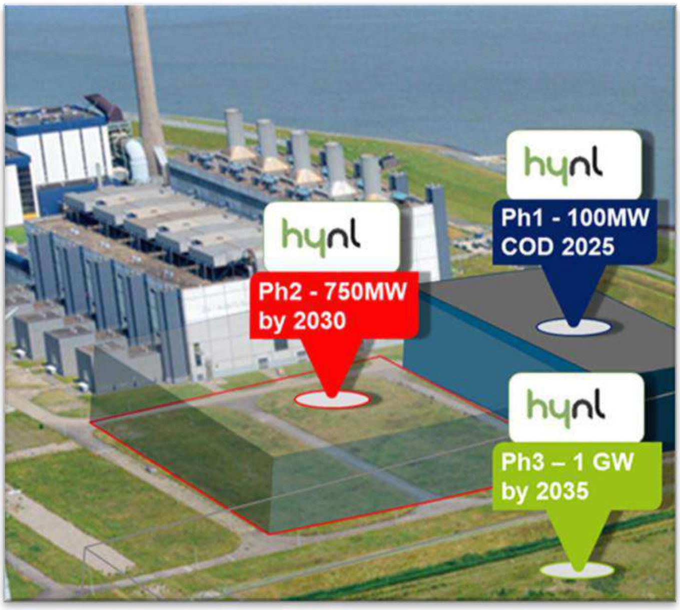


Figure 16: Preliminary visualization of GW-scale Hydrogen production at ENGIE Eemshaven.

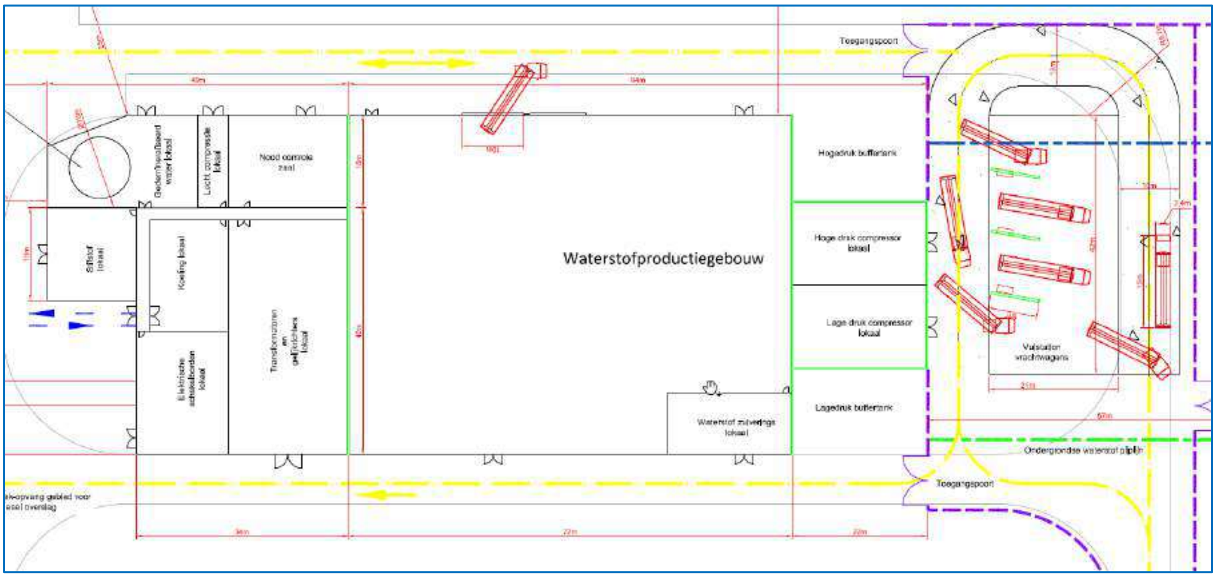


Figure 17: Preliminary lay-out of the Hydrogen plant

3.1.13 O&M Organisation ENGIE (to be)

The O&M organisation of the Hydrogen production 100MW will be integrated in the existing O&M-structure of the ENGIE Eems Powerplant. The current local organisation of the ENGIE has a dedicated organisation for the exploitation of 5 CCGT-units, concerning of a 6 shift organisation for operations, a multi-disciplinary maintenance organisation including maintenance engineering and a dedicated staff. The Powerplant is part of the European organisation for Thermal Generation of ENGIE.

For facilitating the Hydrogen production in addition to the existing Powerplant, the organisation for Operations will add at least one additional FTE per shift and for Maintenance two FTEs. During the construction phase ENGIE decides how to structure a LTSA with the OEM. This agreement may lead to adjustment of the organisational approach mentioned.

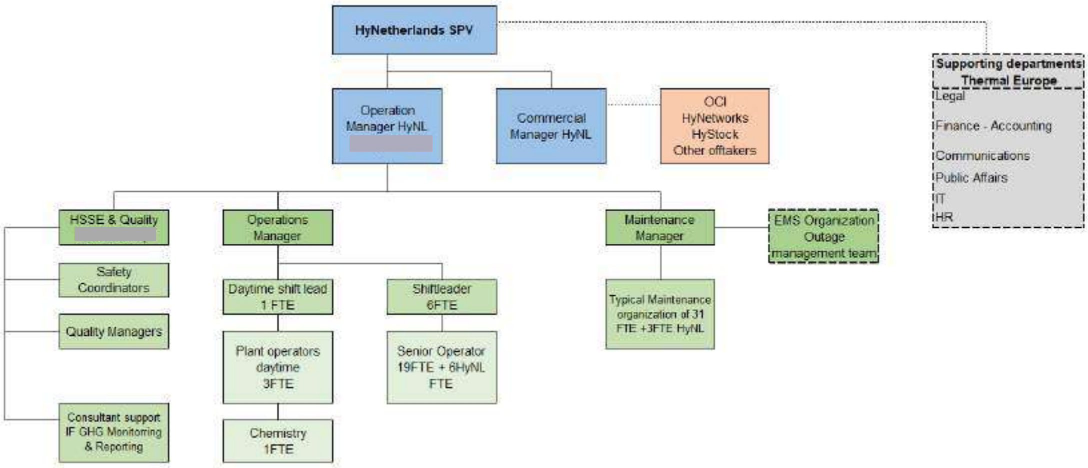


Figure 13: Preliminary new organisation ENGIE site Eemshaven

The O&M team of the existing ENGIE Eems power plant will integrate the operations of the electrolyzer plant into its organisation. The ENGIE Eems power plant entity manager will take over the responsibility of from the General Project Manager at entry into operation and his management team will further distribute relevant tasks into their respective operational teams. Under the shift leader function an additional rotational team of 6 operators will be installed. The same is intended for the maintenance division, in the controls & instrumentation, mechanical and electrical supervisors teams and technicians will be added. Certification of the produced Hydrogen, and eventually end product, will be a complex set up. It is currently being considered whether to source out this activity to a consultant, or to assure additional internal resource(s) will be available.

3.2 Permitting and environmental analysis

3.2.1 Required permits

ENGIE submits an application for an environmental permit under the Environmental Permitting (General Provisions) Act (Wabo) for the aspects of the environment, construction and deviating from the zoning plan as well as an application under the Water Act. This document also concerns a notification within the framework of the Major Accident Hazards Decree 2015. At the same time as this permit application was submitted, a memorandum has been submitted to the Province of Groningen for the purposes of the so-called form-free EIA assessment. It has been confirmed in July 2022 that an EIA is not applicable for the HyNL 100MW project. will not be the case.

ENGIE has submitted for commenting a conceptual draft of the environmental permit application by October 2021 to the Environmental Service Groningen (ESG). By February 2022 the ESG responded verbally with only minor textual corrections to be processed before applying for the environmental permit. The provided studies were concluded to be sufficient; acoustic study (noise), external safety, nitrogen disposition, nature study, assessment BREF Energy Efficiency (2009), inventory Seveso III (BRZO). The form-free EIA assessment is accepted, a full EIA is not marked as required, which is confirmed by the grant of the comparable permit for the Hydrogen project of RWE: Reference competent authority Environmental Service Groningen: GR-VERG-2021-000170, case-number ODG: Z2021-002532. This RWE 50MW-project is comparable to the HyNetherlands 100MW and located in the same industrial area, consequently subject to the same laws and regulations in terms of licensing.

The table below provides an oversight of the main permits identified and the confirmation if eventually needed or not.
The application for the permits under a, b, c1, c2, d and e was submitted in February 28 2022.

Procedure	Necessary	Procedure time	Comment
Spatial planning act (wet ruimtelijke ordening, WRO)			
Zoning plan	Yes; the board of mayor and aldermen of municipality Het Hogeland must formally ratify the qualification for Seveso III (BRZO)	2022	The production of H_2 fits within the zoning plan. Only the establishment of an Seveso III plant must be formally accepted. This is not expected to be a problem on the basis of preliminary consultations.
Environmental Impact Assessment (EIA) Decree (Besluit Milieueffectrapportage, m.e.r) *)			
EIA procedure ('Milieueffectrapportage')	The installation is subject to EIA. The so-called 'form-free EIA assessment' will be submitted at the same time as the Wabo application. Based on the assessment, the province will determine whether it is necessary to provide a full EIA.	T.b.c.	After the kick-off in 2020 and during additional contacts the Environmental Service it has stated that the project is not to expect resulting in significant adverse environmental effects. And thus a full EIA study will not be required. Provides info are assessments on: • External safety • Noise (acoustic) • Nature effects (Nature Protection Act) • Seveso/BRZO (Inventory)
Wabo permit (Omgevingsvergunning)			
Deviation from the zoning plan (Binnenplanse afwijking)	Yes	26 (+6*) + 6** weeks	For establishing a Seveso III plant
Environmental (Onderdeel milieu)	Yes	26 (+6*) + 6** weeks	For the environmental impact of the project

3. Construction (Onderdeel bouw)	Yes	8 (+6*) + 6** weeks	For the construction of the buildings. • To applicate after appointing the preferred EPC-contractor, based on their plant configuration.
d. Nature conservation act (Vergunning Wet natuurbescherming, Wnb)			
1. Species protection (Onderdeel Soortbescherming)	No.	13 (+7*) + 6** weeks	An ecological field research has been carried out. There are no protected species for which an exemption is required
2. Area protection (Onderdeel Gebiedsbescherming)	No.	13 (+7*) + 6** weeks	A nature assessment has been carried out. no significant negative effects are foreseen. A Nature permit is therefore not necessary.
e. Water permit (Watervergunning)			
Inconsistent use (Onderdeel strijdig gebruik)	Yes	26 (+6*) + 6** weeks	ENGIE requires no increase of the already permitted flow rate and thermal load of cooling water. Neither causes the H_2-plant new types of wastewater streams. a permit is required for the alternative use of cooling water

Table 2: Permits required

*) Update: The province of Groningen has ruled that an EIA is not applicable for the project of HyNetherlands 100MW.

3.2.2 Legislation water management

Regarding the use of water, we can distinguish 4 different applications for HyNL use:

- Cooling water
- Demin water to produce H2
- Sanitary water
- Waste water cycle

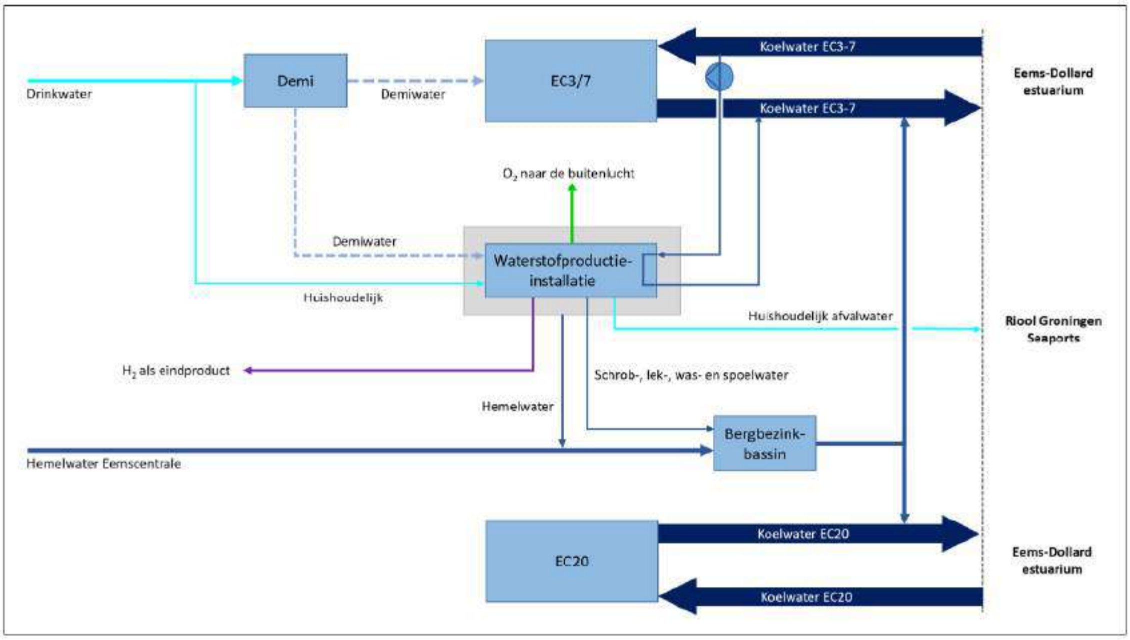


Figure 18: Overview water management

3.2.2.1 Cooling water

Based on ENGIE's calculations, for Hydrogen production, a maximum thermal cooling of 40 MWth is required, taking into account an higher thermal load at the end of plant life due to the drop in efficiency over time. An assessment of the applicable Best Available Techniques (BAT) has been carried out in this permit application with regard to the aspect of water for the application of cooling water on the basis of the BREF Industrial Cooling Systems (ICS, 2001) (section 3.12 of the main document of the permit application). However, this assessment only concerns the additional system parts that will be constructed for Hydrogen production and not the use of the existing cooling water systems for Hydrogen production. In this chapter, the latter is still assessed. Annex 6 of the application has already addressed BAT regarding energy consumption, which is also relevant for the use of cooling.

Based on the BREF Industrial Cooling Systems (ICS, 2001) it is assessed whether the proposed application of cooling water can be regarded as Best Available Technology (BAT).

Due to the selection of this cooling technology no ground or surface water is needed, and hence environmental impact is minimized. The use of cooling capacity may be further reduced in the future depending on the outcome of a study and a pilot project that will be initiated after the project is operational. This project aims at producing desalinated and demineralized water by making use of the project waste heat captured in the cooling water flow. Since the maturity of this application needs to be further investigated, it cannot be integrated in the current scope of the project but if study results demonstrate positive, it will be after the initial years of operation.

3.2.2.2 Demin water to produce Hydrogen

Introduction

The production of Hydrogen by means of electrolysis requires water as a raw material. This requires water that has been stripped of contaminants such as the minerals naturally present in water. Demineralised water is therefore required. The required water quality is comparable to the water used in the electricity production units of the Eems power plant. The BAT (Best Available Technique) assessment of the preparation of demineralised water for Hydrogen production thus does not differ from the assessment carried out for the electricity production units in connection with the procedure for the revision permit in 2013, since that assessment does not depend on the use of the demineralised water. Nevertheless, this chapter still provides an assessment of the Best Available Techniques for the preparation of demineralised water.
No legally prescribed BAT documents exist for the preparation of demineralised water. However, there is a BREF for waste treatment (BREF for Waste Treatment, 2018), including waste water treatment, and an associated implementation decision BAT conclusions for waste treatment. This BAT document is not applicable to the present case. However, by way of indication, it can be stated that in BAT conclusion no. 20 of this document, concerning BAT techniques for water treatment, ENGIE's intended preparation of demineralised water by means of ion exchange is included as BAT for the removal of contaminants from a waste water stream. Ion exchange is specifically included as BAT for the removal of 'ionically dissolved non-biodegradable or inhibiting pollutants', stating general applicability.

- Water sources

  Tap water is used as a water source in the current demineralisation plant at the Eems power plant. Other (theoretically) conceivable sources are saline surface water from the Eems-Dollard Estuary, groundwater and process water. Cleaning up surface water from the Eems-Dollard Estuary makes it necessary to desalinate the salt water. This requires the use of installations with considerable energy consumption and the use and discharge of chemicals, including several substances classified as 'harmful to aquatic organisms'.
  Regardless of whether the use of groundwater or (external) process water as a raw material would be available and feasible, it can be stated that these sources would require more post-treatment on site than tap water as a raw material. Consequently, this would also lead to more, rather than less, wastewater being discharged from the wastewater treatment plant. And thus less favourable for the receiving surface water. It has be checked with and confirmed by the Waterbedrijf Groningen that specifically for this region there is today no concern for water scarcity. ENGIE will however plan for a substitution of the potable water use in the first years after commercial operation of Phase I and definitely for Phase II (750MW) of HyNL.

In the next phases of the HyNetherlands project more demin water will be required for the electrolysis process. For this purpose a new demin water facility is projected sourcing surface water as a feedstock.

- Technology

The two proven techniques for preparing demineralised water are reverse osmosis and ion exchange. The existing plant at the Eems power station uses ion exchangers. Ion filters are used to purify the dissolved substances from the water. The filters have to be cleaned periodically, so-called regeneration. The substances NaOH and HCl are used, which are discharged into the Eems-Dollard Estuary after neutralisation.
In reverse osmosis, water and dissolved substances are separated from each other by means of a semi-permeable membrane under the influence of pressure. This technique will also use NaOH and HCL to neutralise the wastewater before discharge, but the use will be less than when using ion exchangers.
ion exchangers. The disadvantage is that this technique is associated with a significantly higher energy consumption and higher costs in both purchase and operation.
From the point of view of discharging substances, reverse osmosis is preferred to ion exchangers. From the point of view of other environmental aspects, especially energy consumption, ion exchangers may also be preferred.

- Chemicals used

NaOH and HCl are used in both ion exchange and reverse osmosis and are discharged after neutralisation. These substances do not have a classification as (potentially) 'substances of very high concern' or any identified risk with regard to reproduction of aquatic organisms or accumulation in the (aquatic) environment. In the licensing procedure in 2014, these substances were assessed within the system of the 'General Assessment Method' as respectively 'Harmful to Aquatic Organisms' (B(3)) and 'Low risk for aquatic organisms' (B(5)).

- Economic aspects

Apart from individual circumstances, it can generally be stated that the costs for reverse osmosis are expected to be higher than for purification by means of ion exchangers. Looking at the specific situation at the Eems power plant, it is very important with regard to the economic aspect that there is already a demineralisation plant present with sufficient capacity to supply the Hydrogen production plant with sufficient demineralised water in addition to the electricity production units. This means that virtually no investments need to be made for the use of this installation, based on ion exchangers.

- Conclusions

Like electricity production, Hydrogen production also requires water of a high purity, stripped of minerals, among other things. This demineralised water can be prepared using various techniques and with different types of water as a raw material. The assessment of this in terms of the Best Available Techniques does not deviate for the Hydrogen production plant from the assessment of the electricity production units, as already assessed during the procedure for the revision permit in 2013.

Specifically from the point of view of the discharge of chemicals to surface water, it can be stated that the use of tap water as a raw material with reverse osmosis as a purification technique is preferable. From other considerations, such as scarcity of drinking water and energy consumption, other choices may be preferable, however it has been confirmed that this is today not a concern in the project area. With regard to the discharge of chemicals, a demineralisation plant using ion exchangers is preferable to a reverse osmosis plant, but ion exchangers are preferred, particularly in terms of energy consumption. The presence of an existing demineralisation plant of sufficient capacity within the facility also makes it inappropriate from an economic perspective to consider another treatment technique.

In conclusion, from an environmental point of view there is no clear preference for a specific purification technique, but the first operational years planned technique using ion exchangers can be regarded as BAT.

3.2.2.3 Sanitary water

The use of sanitary water is considered for the sanitary installations and cleaning purposes, it will be supplied from the existing potable water supply source.

For those water streams where potential contamination can arise, refer to figure below, specific monitored treatment installations will be installed where possible make use of the existing monitored plant treatment systems. Exceptionally wastewater streams will be isolated to be transported to dedicated permitted treatment facilities.

3.2.2.4 Waste water cycle

No substances are discharged from the Hydrogen production facility that are subject to an ABM test (General Assessment Method 2016) or to an emission test. Such an assessment is therefore not included in this permit application. The assessment of the substances discharged from the demineralisation plant, and therefore also benefiting the Hydrogen production, has already taken place in the 2013 revision permit procedure. A different application of the demineralised water does not affect the results of this assessment and therefore does not have to be carried out again.

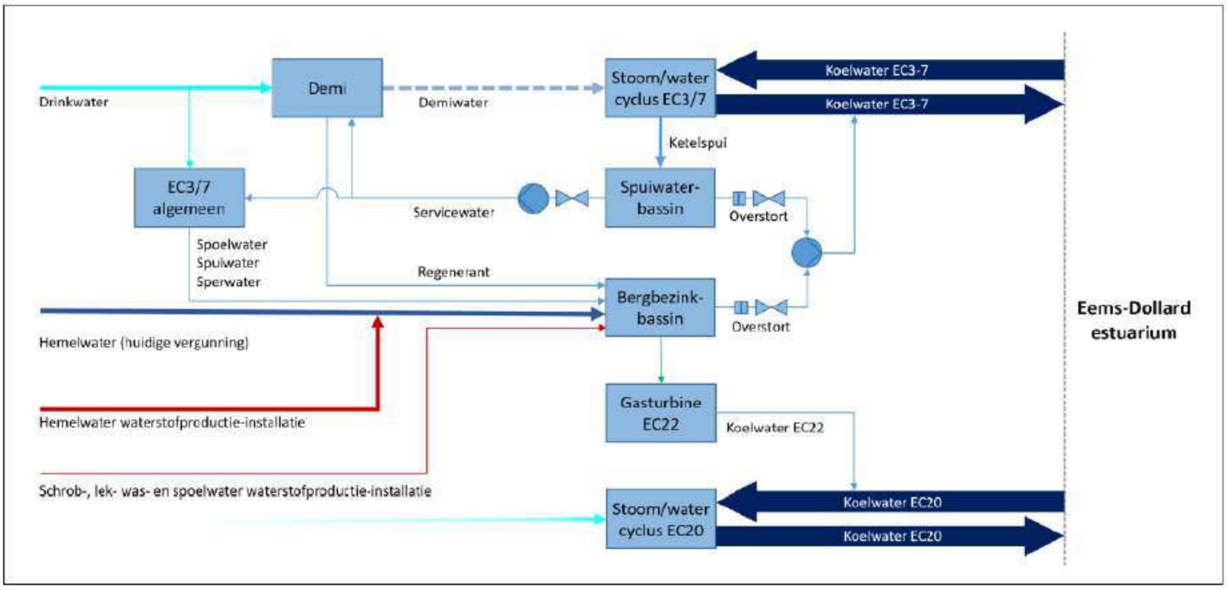


Figure 19: Overview waste water streams

More details about the way HyNL will be compliant to the environmental regulations and measures it will take to limit negative environmental impact can be found it the full environmental permit submission that is currently being evaluated by the relevant competent authorities. Depending on the evaluation of the environmental permit HyNL will comply with any additional requirements raised in such evaluation as well as the recommendations provided therein to limit negative environmental impact.

3.2.3 Construction permit

ENGIE will submit for the permit to build (as part of WABO) after appointing the preferred EPC-contractor, based on their proposed plant configuration. In the request for quotation potential suppliers are invited to present their best offer fit for purpose. This implicitly underlines the ambition of ENGIE to implement the best possible technical solution for the Hydrogen production based on performance without prescribing the technology to use. As this is the approach the FEED has not been executed by definition and shifts the detailed engineering and construction detailed proposal until after the selection of the preferred supplier in Q4 2022.

The application for the permit to build is submitted early Q1 2023 and requires a processing time of 8 weeks (plus 6 weeks for appeal). The permitting file will include all required information as e.g. for construction calculations, fire safety, etc.

Based on the previous executed feasibility study in 2019 ENGIE ensures that the installations can be erected on the reserved plot at the site of the ENGIE Power Plant at the Eemshaven.

3.2.4 Conclusions Ecological Research

- Function of the plan area

The plan area may be important as a breeding ground and foraging area for Peregrine falcon. The plan area may also be of importance to ground-dwelling birds and bats. Harbour porpoise and common seal occur near the plan area in the Wadden Sea.
Finally, the plan area is possibly of importance to various ground-bound mammals fall under the exemption regime of the Province of Province of Groningen.

- Completeness of research data

The conclusions in this report regarding protected species are based on sufficient available and up-to-date information. There are no gaps in knowledge that could affect the conclusions.
The conclusions therefore give no reason to any further investigation. The study is complete. However, if work is carried out during the breeding season, nests of breeding birds must be found, so that measures can be taken to prevent effects on breeding birds. It is recommended to work outside the breeding season.

- Scope of the intervention

As a result of the intervention, foraging grounds of peregrine falcons and bats may disappear. However, it does not concern an essential foraging area. In the vicinity of the plan area there is sufficient alternative foraging area to which peregrine falcons and bats can fly.
Therefore, no long-term effects of the intervention on species or populations are expected.

- Research details

The ecological research executed reports on source investigations and the determination of effects on Natura 2000 areas. This report includes a calculation of the effects of (additional) nitrogen emission on the deposition of Natura 2000 areas). The additional deposition as a result of the project is so limited that effects on conservation objectives can be ruled out in advance.
The aim of the study is to determine whether the intervention could lead to breaches of the rules of the Nature Protection Act. If this is the case for protected areas, it is determined under which conditions a permit can reasonably be obtained or whether an Appropriate Assessment is required to answer this question. If there is a violation of protected species, the conditions under which an exemption can reasonably be obtained are determined.

Based on field research and source research, the following conclusions are drawn:

1) Direct effects as a result of future developments such as loss of surface area, fragmentation or desiccation are not relevant.
2) Indirect effects from light, pollution, optical disturbance and mechanical effects are not relevant.
3) Indirect effects of disturbance through noise/vibration cannot be excluded in advance.

4) No nitrogen deposition values above 0,00 mol/ha/yr are to be expected. Therefore, no negative effects of increased nitrogen deposition will occur.
5) On the basis of the objective data presented in this report, negative effects of the project on the conservation cannot be excluded.

- Appropriate Assessment

It is not expected that an appropriate assessment will be required to determine the impact of noise and other forms of vibration occurring during the works as a result of screwed piles
during the works. N.B. The assessment of the necessity for a permit lies with the competent authority. The conclusion of Bureau Waardenburg has no legal force.

- Follow-up study

The conclusions in this report regarding Natura 2000 areas are based on sufficient available and up-to-date information. No gaps in knowledge have been identified that could affect the conclusions. Therefore, the conclusions do not give rise to any further investigation.

The recommendations listed below are non-statutory measures. They do not have to be taken in order to prevent a breach of the law, but they can contribute to a higher biodiversity of the plan area:

- In the factory that is to be built, it may be possible to install built-in cupboards that can accommodate bats.
- Greenery can be planted on the factory site. The flora and fauna that may occur will strongly depend on the layout and the species found in the vicinity. Herb mixtures are sown regularly. Here it is important to use only indigenous species and preferably species that also occur in the vicinity. Such a mixture attracts insects such as butterflies and bees. Sowing is not necessary but can ensure that a field quickly looks attractive and gives a quick start to greater biodiversity on the plot.
- Possibly, the plant can be provided with a green roof.

3.2.5 Green House Gas avoidance

3.2.5.1 Introduction

To reach global greenhouse gases emissions reduction, energy consumers need to displace fossil energy carriers produced across the globe. These energy carriers are characterized by a high energy density, easiness to transport and store through existing infrastructure to be converted into fuel for transport, heat and power. HyNetherlands project (“HyNL”) aims at developing, building and operating one of the first industrial value chains for the production of e-methanol, combining renewable energy and biogenic Carbon Dioxide (“CO_2”) in the North of the Netherlands (Groningen province). Thereby HyNL will deploy the next generation of renewable-based energy carriers with matching characteristics as its fossil equivalent.

With a targeted production capacity of respectively 56,000 tons of e-methanol; 14,000 tons of Hydrogen and 77,500 tons of biogenic CO_2 per year, it will multiply by 14 the size of current state-of-the-art installations applying similar power to methanol process.

HyNetherlands will also trigger:

- the market and commercialization of new renewable products (in the transport sector, especially (but not only) the shipping sector)
- the avoidance of 140 kilo tons per year of CO2 starting from end 2025
- the circularity of biogenic CO2 from non-recyclable waste as well as potentially the circularity of oxygen
- the overall efficiency improvement of water electrolysis process against current standards

Furthermore, HyNL will contribute to triggering early investments in open access infrastructure retrofit towards Hydrogen (Hydrogen backbone and underground storage in salt caverns) by 2025.

The strategic approach adopted ensures that all steps (renewable energy, biogenic CO_2 sourcing, e-methanol production and infrastructure dimensioning) are capable of scaling up (thanks to current design, dimensioning and site capacities).

To achieve this ambition, three leading companies in their field (ENGIE, OCI and EEW) are collaborating towards the first of a kind e-methanol project.

As an importer of fossil energies from overseas sources (with 60% imported energy in 2019), Europe has a well distributed oil & gas infrastructure. The HyNL project's primary goal is to valorize this asset legacy to accelerate energy transition in the European Union ("EU") and achieve EU Green Deal targets at lower cost. Considering renewable-based energy carrier production, the project makes use of the 212 GW offshore wind potential of the North Sea , which is the highest potential in the EU .

HyNL will combine renewable Hydrogen and source biogenic CO_2 to produce e-methanol, in order to decarbonize heavy duty and hard-to-abate applications (maritime sector in the short term and chemical sector in the medium term). At the same time, Europe can become more independent regarding energy imports and increase supply security.

3.2.5.2 Absolute GHG emission avoidance

- **Summary**

The HyNL project will produce Hydrogen from renewable electricity and capture biogenic CO_2 from a waste-to-energy plant to produce e-methanol (56,000 tonnes methanol/year). Additionally, it produces volumes of renewable Hydrogen to be valorised for mobility (800 tonnes H_2/year) and renewable Hydrogen for other uses (2,757 tonnes H_2/year). During the Hydrogen production, oxygen will be produced and potentially valorised in a nearby waste gasification project (out of scope project) under development. Furthermore, during the e-methanol production steam is produced, that is valorised in nearby industries.

Thus, HyNL has two principal products, i.e. e-methanol and Hydrogen, and two by-products, i.e. oxygen and steam.

The GHG emissions from the HyNL project are – 219,060 ton of CO_2 equivalent ("CO_2 e") (for the period of 10 years). When compared to methanol in the reference scenario, for that same quantity of methanol and renewable Hydrogen it has emissions of 1,162,700 tCO_2e (for the same period of 10 years).

- **Brief description calculation**

<u>Project emissions</u>

Based on the annual production of methanol (56,000 tons methanol/year), a principle product, the volume requirements of (biogenic) carbon dioxide (77,458 tons CO_2/year) and Hydrogen (10,500 tons H_2/ year) were calculated, considering technical constraints of the existing methanol plant. Additionally, in relation with the other principal product (renewable Hydrogen), a volume of 800 tons per year of H_2 for mobility and 2,757 tons per year of H_2 for other uses was added.

Based on these parameters, inputs requirements and associated emissions were calculated, based on input data from the project partners (OCI, EEW and ENGIE). Mass and energy balances were calculated for the three systems, being the electrolysis plant, the carbon capture plant and methanol production plant. With these 3 systems, the most relevant inputs and outputs entering and leaving the HyNL project were quantified. (e.g. 45 GWh/year of steam valorisation at the methanol unit).

Furthermore, the input/output figures are summed for the 10 years of operation and multiplied by their respective carbon intensities. The carbon intensities are defined by the data sources found in the Excel File (in the sheets Reference Conversion Factors and project Conversion Factors). The Project assumptions to define the inputs and outputs are defined in the sheet Assumptions.

The production of the two by-products is considered as generating negative carbon intensities in the Project GHG emissions.

For 10 years of operation, the following project emissions happen in relation with the production of 560,000 tons of methanol and 35,573 tons of Hydrogen (for mobility and other uses):

1) Methanol plant: 186,778 tCO_2e from natural gas consumption for process heat, 194 tCO_2e from wastewater treatment and – 100,996 tCO_2e from steam by-production credit and + 770,000 tCO_2e for end-of-life combustion of the methanol product. – Other inputs are de minimis;
2) Electrolysis plant: 1,219 tCO_2e from demineralised water consumption and – 356,065 tCO_2e from oxygen by-production credit – Other inputs are de minimis;
3) CO_2 capture and transportation system: - 774,576 tCO_2e of CO_2 captured, 5,393 tCO_2e for utilities and wastewater treatment and 48,993 tCO_2e for displaced electricity production reduction as the part of heat produced by the waste-to-energy plant is used for carbon capture and thus no longer used for electricity production.

All electricity consumption is considered as having a carbon intensity of 0 tCO_2e/MWh.
The sum of these values leads to the total emissions of the project scenario of -219,060 tCO_2e.

Reference emissions

The project emissions are compared to the reference emissions of the principal products, i.e. the methanol and Hydrogen. The reference carbon intensity of methanol is 82.5 grams of CO_2e per Mega Joule (“gCO_2e/MJ”), after unit conversion of methanol (19.90 Mega Joule per kilogram – “MJ/kg”) and multiplication with methanol volume, the reference emissions for methanol are 919,380 tCO_2e. The 82.5 gCO_2e/MJ represents cradle-to-grave emissions, meaning it already considers combustion or decomposition of the methanol. For Hydrogen the carbon intensity used is 6.84 $kgCO_2e$/kg H_2, this is also multiplied with the Hydrogen volumes. The reference emissions for the Hydrogen are 243,320 tCO_2e. Both carbon intensity factors of methanol and Hydrogen are found in the Ref Conversion Factor of the GHG excel file. Summing both, the reference scenario would emit in 10 years 1,162,700 tCO_2e.

Absolute avoided emissions

To calculate absolute avoided GHG emissions, the equation was used:

$$\Delta GHG_{abs} = \sum_{y=1}^{10} (Ref_y - Proj_y)$$

When thus subtracting project emissions from reference emissions, the HyNL overall GHG savings are 1,381,760 tCO_2e.

3.3 Procurement and construction Hydrogen Plant

3.3.1 Procurement approach

- Feasibility Study

In 2019 a detailed feasibility study had been commissioned by Tractebel Engineering. The scope of this study included amongst others assessing the available interfaces and services that are available from the existing ENGIE Eems power plant, the interpretation of soil conditions for the structural design, obtaining technical inputs and budgetary offers with technical details from 6 electrolyzer suppliers, assessing the grid interconnection technical feasibility and configuring the Hydrogen production process and conceptual set up of the plant. Based on the offers received and data available from consultant databases, initial CAPEX and OPEX estimations were made and evaluated in a preliminary business model. As the conclusions of these feasibility study were positive, ENGIE concluded to continue the development of the project.

- Engineering, Procurement and Commissioning Contracting

Since the feasibility study concluded that both Alkaline and PEM (Polymer Electrolyte Membrane) electrolyzer technology are suitable for this project, it was decided not to proceed the feasibility study with a FEED (Front End Engineering and Design) that would focus on a single technology, but instead to start developing a Minimum Functional Specification (MFS). The MFS and Scope of Work have been submitted to ENGIE development team end 2021 by Tractebel Engineering for final review. This MFS provides the basis of design, standards to be complied with, safety concepts, etc. Together with the Terms & Conditions and the Scope of Work which defines the rules and regulations, project management, testing, training and other requirements, these documents serve as the basis of the ongoing EPC Contractor tendering process.

End 2021 a Request For Information (RFI) process had been launched, all the electrolyzer suppliers that participated in the 2019 feasibility study were asked to provide with their proposed EPC partner to execute the project under a lump sum turnkey EPC approach. Finally, 5 EPC consortia confirmed available capacity, interest and motivation to participate in the tender process.

For each EPC supplier, ENGIE conducted a first-level due diligence check of the names of individuals and companies against several hundred global watch lists, including anti-money laundering, anti-bribery, sanctions, and other financial corruption and crime databases. These global lists provide a useful first-level screening tool to detect potential red flags related to corrupt activities and other key risks, reports and evaluation are structured as the following:

- Ethics & Compliance
- Corruption & Legal Risks
- Human Rights
- Corporate Governance
- Reputation Risks
- Financial Risks
- Country and Sectorial Risks

3.3.2 Safety

Respecting Health, Safety, Security and Environment (HSSE) is a top priority for ENGIE and this is particularly true in the context of industrial projects such as the one envisaged here. A project is not a success if HSSE management is not a success. In addition, a proper HSSE culture induces a continuous improvement culture, beneficial to the whole project and operations community.

For the HyNetherlands project, HSSE is considered from the business development phase (Initiate and Define) and through all the phases of project execution (Design, Build and Test & Commissioning) until the handover to Operations. As of the operational phase the existing policies embedded in the existing HSSE and O&M organisation will take over and where needed, adjusted.

Due to the volatile and explosive nature of Hydrogen, ENGIE has developed with internal and external process safety experts a framework for Hydrogen projects. This framework, 'Safety Concept' is the starting point for the process safety design, it has been customized to the HyNetherlands project and is part of the EPC tendering documents and eventually the EPC Contract.

During the development phase, HSSE is considered in the project budget, the project organisation, the contract specifications and the selection of contractors. A qualitative risk assessment will be performed and the HSSE management plan is developed accordingly.

During the project detailed design phase, a number of related HSSE activities such as process safety risk assessment and mitigation, identification and mitigation of occupational health & safety risks during construction, test and commissioning will be performed. During construction, test & commissioning phase main focus will be a physically on-site monitoring of compliance to the before set policies and procedures.

The safety aspects to be considered by the EPC contractor will be described in the tendering documents (technical Sections of the request for proposals) and will cover the following items:

- Industrial Emission Directive;
- SEVESO lll;
- Applicable European Directives requirements (ATEX, Pressure Vessels (PED), Machinery, Low Voltage Directive (LVD), Electromagnetic compatibility (EMC));
- Process safety (HAZOP (Hazard Operability); Fire and explosion risk analysis; SIL (Safety Integrity Level); Emergency Shutdown System etc.);
- Occupational safety (Lighting; Hazardous substances; Ergonomics; Accessibility; etc..);
- Emergency and Rescue;
- Hazardous substances risk management: Hydrogen, Oxygen, electrolytes, SF6;
- Risks related to High and Low voltage;
- Management of construction HSE;
- ATEX zoning and Safety distances;

The following is a non-exhaustive typical list of deliverables to be produced by the technical team:

a. *<u>During Business Development phase:</u>*

- HSSE risk identification and assessment
- HSSE clauses in shareholders' agreement, joint development agreement, consortium agreement
- HSSE clauses in requests for proposals and contracts (EPC, construction contracts, supply contracts, Owner's Engineer or other services contracts including EPCM)
- Contractor assessment on HSSE matters
- HSSE Management Plan (first issue)
- HSSE organisation chart
- Process safety risk assessment (HAZID, HAZOP or equivalent, can be performed in project execution phase according to the project nature)

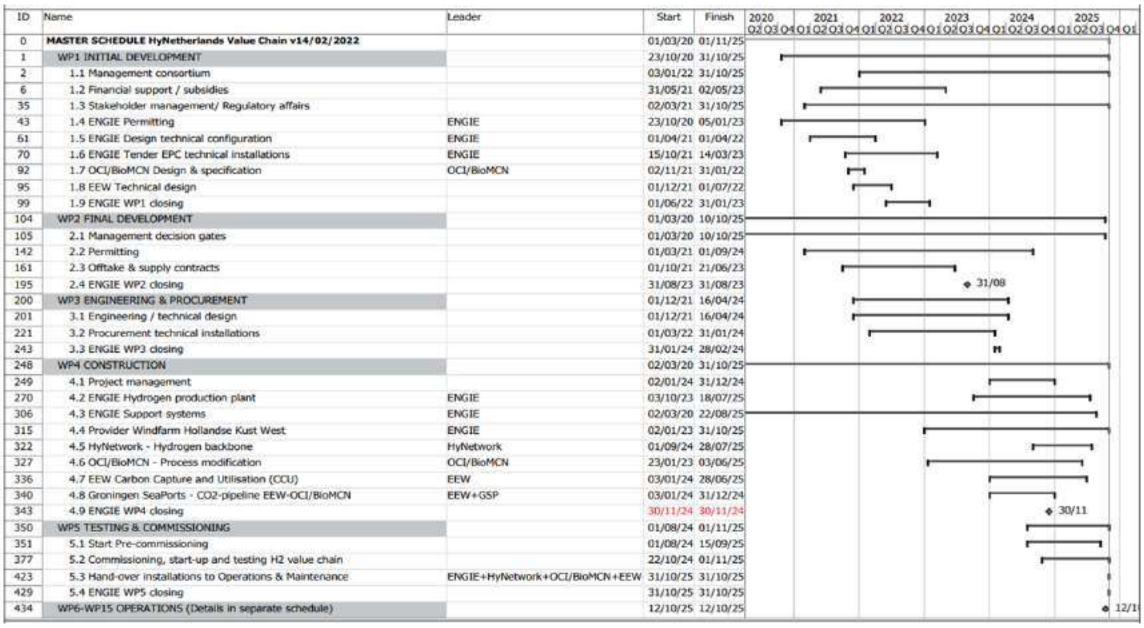
b. *<u>During Project Execution Phase :</u>*

- HSSE Management Plan (for execution)
- Emergency response plan
- Construction site occupancy and traffic plan
- Periodically HSSE reporting (including KPI's, accidents and incidents reports, etc)
- Safety files to be handed over to the operator

As the project take place in existing operating facilities, the HSSE policies and procedures will be applicable and adjusted if needed.

3.3.3 Project timeline

ENGIE concludes the Business Development of the HyNetherlands 100MW mid 2023 by reaching the Final Investment Decision. The detailed engineering, procurement of main equipment and construction start consequently and the latter will be finalized early 2025. The testing and commissioning in the plant and the value chain takes place during 2025 and end by the hand-over for production at November 1st of that same year.
ENGIE has defined a long-term H_2 roadmap for future expansion of the electrolysis capacity at the Eemshaven project site. The 100 MWe ENGIE H2 plant has the objective to be a fast-track large-scale demonstration project to trigger the H2 market in the region, and to demonstrate the bankability, scalability and replicability potential at the site, region and throughout EU. The first H2 uses will focus on the refinery sector (e-methanol for maritime applications) and to H2 for mobility. The objective of the ENGIE H2 roadmap is to reach 850 MWe by 2030 and 1.85 GWe by early 2030´s, reaching over 200 ktpa H_2 production, with a diversity of usage from chemical sector to mobility to steel industry and others.



ID	Name	Leader	Start	Finish
0	**MASTER SCHEDULE HyNetherlands Value Chain v14/02/2022**		01/03/20	01/11/25
1	WP1 INITIAL DEVELOPMENT		23/10/20	31/10/25
2	1.1 Management consortium		03/01/22	31/10/25
6	1.2 Financial support / subsidies		31/05/21	02/05/23
35	1.3 Stakeholder management/ Regulatory affairs		02/03/21	31/10/25
43	1.4 ENGIE Permitting	ENGIE	23/10/20	05/01/23
61	1.5 ENGIE Design technical configuration	ENGIE	01/04/21	01/04/22
70	1.6 ENGIE Tender EPC technical installations	ENGIE	15/10/21	14/03/23
92	1.7 OCI/BioMCN Design & specification	OCI/BioMCN	02/11/21	31/01/22
95	1.8 EEW Technical design		01/12/21	01/07/22
99	1.9 ENGIE WP1 closing		01/06/22	31/01/23
104	WP2 FINAL DEVELOPMENT		01/03/20	10/10/25
105	2.1 Management decision gates		01/03/20	10/10/25
142	2.2 Permitting		01/03/21	01/09/24
161	2.3 Offtake & supply contracts		01/10/21	21/06/23
195	2.4 ENGIE WP2 closing		31/08/23	31/08/23
200	WP3 ENGINEERING & PROCUREMENT		01/12/21	16/04/24
201	3.1 Engineering / technical design		01/12/21	16/04/24
221	3.2 Procurement technical installations		01/03/22	31/01/24
243	3.3 ENGIE WP3 closing		31/01/24	28/02/24
248	WP4 CONSTRUCTION		02/03/20	31/10/25
249	4.1 Project management		02/01/24	31/12/24
270	4.2 ENGIE Hydrogen production plant	ENGIE	03/10/23	18/07/25
306	4.3 ENGIE Support systems	ENGIE	02/03/20	22/08/25
315	4.4 Provider Windfarm Hollandse Kust West	ENGIE	02/01/23	31/10/25
322	4.5 HyNetwork - Hydrogen backbone	HyNetwork	01/09/24	28/07/25
327	4.6 OCI/BioMCN - Process modification	OCI/BioMCN	23/01/23	03/06/25
336	4.7 EEW Carbon Capture and Utilisation (CCU)	EEW	03/01/24	28/06/25
340	4.8 Groningen SeaPorts - CO2-pipeline EEW-OCI/BioMCN	EEW+GSP	03/01/24	31/12/24
343	4.9 ENGIE WP4 closing		30/11/24	30/11/24
350	WP5 TESTING & COMMISSIONING		01/08/24	01/11/25
351	5.1 Start Pre-commissioning		01/08/24	15/09/25
377	5.2 Commissioning, start-up and testing H2 value chain		22/10/24	01/11/25
423	5.3 Hand-over installations to Operations & Maintenance	ENGIE+HyNetwork+OCI/BioMCN+EEW	31/10/25	31/10/25
429	5.4 ENGIE WP5 closing		31/10/25	31/10/25
434	WP6-WP15 OPERATIONS (Details in separate schedule)		12/10/25	12/10/25

Figure 20: HyNetherlands Phase 1 100MW Indicative timeline

3.3.3.1 Testing and Commissioning

- Introduction

While part of the equipment will be delivered and installed during the construction phase, the remaining part of the installation will be put in place during the phase of testing and commissioning. Once all the technology is mounted by all three partners, cold commissioning starts, followed by hot commissioning, trial run, performance and reliability testing of the plants including the tests related to the use of Hynetwork Hydrogen backbone and Groningen Seaports CO_2 transport pipe. A critical external milestone that needs to be established prior to commence hot commissioning and trial runs at BioMCN e-methanol facility is the readiness of the Hynetwork backbone phase I. At the end of the reliability and performance testing, the project will Enter Into Operation, 1 November 2025.

- ENGIE activities

Starting early 2025, the connection between the plant and the backbone will be established by Hynetwork. Thereafter; commissioning and testing works take place for the ENGIE Hydrogen plant (see below, project activities). First trial delivery of oxygen is foreseen during the commissioning period. Also commissioning and testing of the filling station for the mobility offtake of the Hydrogen will take place. In parallel to these activities ENGIE will assure accreditation of the EMS application that will automize the Hydrogen certification and include its testing in the commissioning activities.

- EEW activities

After an 18-month construction time, cold commissioning is expected to start at the end of Q2 2025. Cold commissioning of the carbon capture units is expected to start in May 2025. This is also when the tie in of the CO_2 pipeline will take place. Beforehand, theoretical and practical training of the staff will be realised. For June and July 2025, hot commissioning is expected. It is carried out by the plant manufacturer in collaboration with the project team and site staff. After that, performance tests in collaboration with BioMCN can be carried out in Q3-4 2025. Then, by November 1st, 2025, the plant can start full operation.

- BioMCN activities

The compressor to compress imported CO_2 from 3 barg to 28 barg will be commissioned. With the CO_2 import system ready, BioMCN is ready to commissioning activities related to e-methanol production and to receive first Hydrogen for trial. Commissioning and start-up will be done in house by the BioMCN automation team. BioMCN has an in-house instruction team and panel operator training simulators for its two operation lines. The new situation will be modelled in these simulators so every operator can train at any moment that suits well and well in advance of the actual convergence to H_2 blending.
The lessons learned from commissioning and initial operational REX from the Djewels-1 project to be commissioned in H1 2025, can and will be used for the HyNetherlands project.

- Project activities

In the last stage of the project, starting early 2025, commissioning and testing works start to take place. Starting in May 2025, the electrolyzer, the carbon capture and e-methanol project individual commissioning activities will start to synchronize in order to be ready to start testing the entire value chain as of September. Important external milestones that will need to be achieved at this point in time, are the readiness of the Hynetwork backbone (Sept 2025) and the GSP CO_2 pipe (May 2025), Prior to enter into operation, a 14-day Reliability Test run will take place, during which also plant Flexibility and Performance Tests will be performed. Performance tests will be performed considering not only the full load condition of the ENGIE electrolyzer plant, but also 3 other load points to assure the guaranteed performance at part load operation can be met as well. In case guaranteed performances for the Hydrogen plant are not met, liquidated damages will be payable by the EPC Contractor to ENGIE.

The electrolyzer EPC contractor and the CCU unit engineering contractor will be required to provide as part of its scope, a theoretical and on-the-job-training program. The theoretical program should be finished during the construction phase followed by the on the job training which will start during testing and commissioning.

When the electrolyzer and CCU plants are ready to start supplying Hydrogen and biogenic CO_2, the Hydrogen offtake agreement will arbitrate the commercial conditions. To manage the

Hydrogen supply on a daily and short-term basis, communication protocols (including emergency response conditions) amongst ENGIE-EEW-OCI will be established prior to the first supply of Hydrogen. These protocols will be updated regularly during the operational phase. For the Hydrogen supply these protocols will include Hynetwork Services and for the CO_2 transport, Groningen Seaports as they are responsible for the transport from point a to b.
After all commissioning and performance tests have been completed, all procedures and policies have been validated and implemented, the SteerCo will jointly evaluate if all conditions to enter into operation have been met and issue an operation readiness & completion certificate to the project.

3.3.4 Risk management

This section summarizes the key risks that have been identified for the HyNL project and their corresponding mitigation strategies. The below risk regarding the Hydrogen production plant refer to the HyNL Risk Register, containing a complete overview of risks and mitigation strategies, including risk heat maps based on consequence and likelihood rating.

3.3.4.1 Technical risk

Risk: A final selection of the 100 MW electrolyzer technology has not been made.
Mitigation: HyNetherlands aims at receiving the best offer for the best performance in the defined production profile. Project key drivers shall be clear for the project team and have been shared with potential suppliers/contractors. Five Energy Procurement Commissioning ("EPC") contractors have confirmed their support for the project and willing to make a proposal. Moreover, a conceptual environmental permit request has been submitted in November 2021 considering the 'worst of the 2 technologies' in terms of environmental impact. In the feedback received on 18 February 2022 from the authorities it is stated that all the content of the conceptual request complied with the requirements. An application for full permitting has been submitted on 28 Feb 2022; on these basis, environmental permit is expected to be obtained within approximately 36 weeks.
*Risk***:** The upscaling to 100 MW of the electrolyzer, as mentioned the first of a kind of this size, might result in production problems. Also the external dependency for raw materials such as iridium, platinum or steels and potential infancy problems with the technology might have the same impact.
Mitigation: Contractual agreement with performance Liquidated Damages ("LDs"), a close follow-up of the engineering (with an Owner's Engineer) and execution, frequent contact with the vendors on the details of increasing production capacity and in house expert team shortlisting only those suppliers with proper track record.
Risk: Due to technological or technical issues with the electrolyzer, the performance and efficiency of the plant can be lower than contracted. This potentially leads to a lower production capacity and lower Hydrogen quality.

Mitigation: Effort will be taken to avoid this issue by checking references, track record, etc. of the suppliers and mitigation/LDs will be included in the contract. Moreover, a QA/QC-mission with e.g. BUGEN EMS/ TE/LBE/Crigen will be implemented during execution and commissioning. Finally, ENGIE performed and will perform simulation of plant performance in bankable software under a wide range of operational scenarios, with support of the OEMs. In particular, the HyEss performance tool under development by ENGIE, will allow a first validation with the real project planned which is planned in Q2 2022.

Risk: In case of design errors, construction errors or malfunctioning of the technical installations at the electrolyzer plant, there is a risk of fire or explosion . This will cause business interruption and can have a severe impact on staff and/or existing facilities in and around the plant.

Mitigation: ENGIE foresees a thorough QRA-assessment and implementation of mitigation measures where applicable. Specifically for Hydrogen project a 'Safety Concept' minimum design requirement has been developed and has been adjusted to reflect the ENGIE Hydrogen plant specificities, this document is part of the EPC MFS. H_2 detection, fire protection etc. will be implemented according to Dutch legislation (PvE, etc). Relevant EPC design studies, validation and approval steps will be specified and followed up by ENGIE with Owners Engineer during implementation. Moreover, the Quality management plan will be developed by the EPC contractor, and quality supervision will be foreseen during construction and commissioning. ENGIE Owners Engineer qualified personnel will validate and report any deviations from the approved design plan. It will be assured that the control systems are designed fail safe and necessary tests will be made to demonstrate this.

3.3.4.2 Financial risk

Risk: Not getting relevant financial support from external funds (risk related to the financing plan).

Mitigation: several side actions have been taken in order to a) maximise the chances of success (strengthening the contractual strategy of the project and its maturity by securing a PPA with GEM/OW, an e-methanol Agreement with an offtaker with a good credit rating; engaging with funding professionals for calculations, review and drafting support as of October 2021, creating strong cross-company teams fully dedicated to the submission; obtaining from the Dutch government an “indication of awarding pre-notification” for the IPCEI funding already in 2021), and b) determining credible funding alternatives (subsidy schemes in the Netherlands and at European level, including 'upscaling fund'; If needed, the contribution of sponsors could be increased and discussions with lenders could be reopened to fund the plant via a project financing.

Risk: Reimbursement of the subsidy in case the subsidy conditions are not met (risk related to the business plan). This risk could derive from delays on the offtake or HyNetwork side, delays on the EPC side, or delays on the power supply side

*Mitigation***:** the risk will be mitigated by pushing the negotiation of contracts for power sourcing, EPC, e-methanol offtake. Specific liquidated damages will be added in these contracts to mitigate this risk.

Risk: Not finding off taker ready to pay for premium price (risk related to the business plan). This risk could be due to the fact that renewable Hydrogen is up to three times more expensive than conventional H_2, leading to higher LCOP for e-methanol; a flexible PPA would still induce still a higher price;

Mitigation: the mitigation actions hinge on a detailed marketing (including dedicated communication) negotiation strategy, focusing for instance on finding offtakers not in need of RED2 compliance but only "renewable H_2" in order to increase the load factor of the electrolyser and lower the H_2 price or offtakers for e-methanol ready to pay the premium and to take 100% of the volume; The premium could also be decreased by securing additional opex subsidies (such as SDE++ and HBE by targeting dutch based offtakers in fuel supply)

Risk: Price level of end product not competitive (risk related to the business plan). Such risk could derive from too low e-methanol price compared to feedstock prices for CO_2 and H_2 (currently no sales market for e-methanol). Potential other, cheaper feedstocks for methanol can be produced by other players, leading to similar emission reduction for clients. Moreover, the competition with other low carbon fuels could also be a triggering factor, inasmuch as the development of International Maritime Organisation ("IMO") regulations and the implementation of opt-ins at Member State level.

Mitigation: in order to mitigate this risk, a thorough assessment via a market study on bio methanol will be expanded with e-methanol. LOI of e-methanol off takers will equally provide early indication of actual price levels for requested RED compliant e-methanol sourced from biogenic CO_2.

Risk: Delayed certification of whole supply chain (from electricity to H_2 to e-methanol), including Life Cycle Assessment ("LCA"), due to a delay in the adoption of the Delegated Act of the EC. Such delay would have an impact on the gathering of the premium on e-methanol sales (as would not be a RED compliant product).

Mitigation: the planned mitigation will entail the certification application plan including LCA, with preliminary certification ready before start up. Currently, data from stakeholders involved have been gathered.

3.3.4.3 Operational risk

Risk: A mismatch between produced offtake power under the PPA and the Hydrogen plant H_2 offtake might arise in such case, ENGIE cannot consume but still pays the contracted PPA's resulting in increased OPEX.

Mitigation: (a) negotiate a better option/flexibility in the PPA, (b) sell the unconsumed energy to a third party , (c) model how to reduce the risk of making loss on the sold surplus energy, (d) make use of the salt cavern storage HyStock, (e) foresee flexibility in the offtake agreement based on (exceptional) weather conditions. EMSA has been established to structure the sale of the excess power between GEMS and HyNL (EMSA offer received 0,4k/a). A market product will be offered to manage the market exposure on the project level and a second track will be opened to receive power from other parties than the current lead.

Risk: Due to excessive natural gas prices, the production of methanol might be stopped (e-methanol production is linked to grey methanol at BioMCN). This would also result in no offtake of H_2 and biogenic CO_2. This will eventually have a financial impact.

Mitigation: BioMCN can max. afford a price level of max. 30 euro/MWh. Two price levels will be defined, once e-methanol offtake price and legislation (RED and ETS) are stabilized: (I)- If the first gas price level is reached, BioMCN will stop production on one of the two lines. The still producing line will absorb the Hydrogen and biogenic CO_2. ENGIE will apply a production strategy towards filling storage (linepack or salt cavern), (ii)- If the second gas price level is reached, BioMCN will stop production. Biogenic CO_2 production will be also stopped, ENGIE will continue producing Hydrogen, while orient production strategy towards filling in storage (linepack or salt cavern once in operation), (iii).- If gas price goes back to normal, biogenic CO_2 production restarts and storage will be emptied to feed e-methanol production at a higher than nominal rate (1.8tph vs 1.3tph), (iv)- If gas prices remain high for a long period of time, Hydrogen production will have to stop and alternative (temporary) offtake to be explored. For the long term BioMCN aims to scale up the import of H_2 and CO_2 so the dependency of natural gas (price) will become less. In the future the NG feed flow will be smaller or even negligible.

Another mitigation that has recently started, is to assess the feasibility of operating the methanol production plant without natural gas, this will involve higher CAPEX figures than the base case scenario and are being investigated.

- Infrastructure out of project scope not ready for use

Risk: The Hynetwork Hydrogen pipeline that will transport Hydrogen from the electrolyzer plant to BioMCN is still in development. Project delays of the pipeline will have a direct impact on the implementation of the HyNL project leading to unavailability of H_2 supply to BioMCN and biogenic CO_2 cannot be fed to the BioMCN plant .

Mitigation: the project planning allows lining up with Hynetwork about their implementation timeline and to stay informed on their progress. Moreover, the FID of the HyNL project is aligned to the timeline of the permitting process of Hynetwork. Commercial agreement meetings will be launched after Q1 2022. Prior to signing the contract with Hynetwork it will be clear if the ministry of economic affairs has released the Rijkscoördinatieregeling, that is applicable to projects of strategic nature and ensures the legislative certainty that the project will be implemented.

Risk: Groningen Seaports (GSP) might face delays in constructing the pipeline that will transport biogenic CO_2 from EEW to BioMCN. No supply of gaseous biogenic CO_2 to BioMCN will also delay the possibility to supply renewable H_2 from ENGIE to BioMCN and the start of e-methanol production will be delayed.

Mitigation: A realistic project planning is put forward, a piping trajectory with Groningen Seaports ("GSP") controlled area has already been identified and frequent meetings with Groningen Seaports are scheduled. This will allow for alignment of the various project timelines.

- Regulatory

Risk: The contracts for the required PPA are not ready before Final Investment Decision ("FID") due to limited availability of sources or because the anticipated power supplier does not win the HKW tender. This would result in no or insufficient PPAs contracted, limiting the RED2 compliant power production capacity, and no or a reduced offtake by BioMCN.

Mitigation: ENGIE commits to align with ENGIE GEMS subsidiary for Energy sourcing and EMSA to start identifying and preparing the PPA-structure timely. Also other bidders for the HKW project have been identified and a plan B is ready if the anticipated supplier does not win the tender. A conditional FID to have signed/initialized contract(s) is in place and power sourcing via windfarm HKW is in progress. Irrevocable granting of windfarm HKW is expected by Q4 of 2022. A third mitigation plan, based on power sourcing from RED compliant local onshore renewables is also ready in case of failure in the HKW sourcing.

Risk: Non RED2 compliant power supply for the electrolyzer would result in the production of fuels that are not RED2 compliant. In such case, the fuel cannot be sold to the main offtaker. This risk can be induced by delays in the publication of the RED2 delegated act. (for electricity supply and GHG avoidance) or stringent RED2 rules that are not compatible with the available power sources.

Mitigation: The business case and technical design are based on the most conservative RED2 criteria assumed in January 2022 and the requirements can be relaxed if finally the RED2 act will allow. ENGIE will continuously explore how RED2 will be implemented, how H_2 will be certified RED Compliant, who will provide this certificate on which basis and what the importance of the EMS is in this respect. Scenarios with offtake that could ease the required compliancy with RED2 will be explored. Moreover, the technical design considers a fully flexible plant that can follow the offshore wind profile on a 15min basis. The focus remains on HKW as only this project currently qualifies for RED2. REX on other windfarms with GEMS has been provided. The plan B is to contact the winner of the HKW tender for energy sourcing.

- Hydrogen quality from the backbone

Risk: The Hydrogen delivered to BioMCN might not meet the quality specifications due to high Sulphur content from other sources than ENGIE Hydrogen plant. Consequence is that e-methanol plant will need to be stopped.

Mitigation: Catalyst vendor Clariant has been involved to find a solution. BioMCN/Hynetwork/Clariant together decided to mix the imported H_2 with the natural gas feed stream so the Sulphur will be removed in the existing desulphurization vessels. After the first month of operation H_2-gas analysis shall proof that the quality of the H_2-gas from the H_2-backbone is good enough for direct use in the methanol synthesis loop. Periodic sampling of H_2 at Battery Limit shall be worked out to check the quality of imported H_2.

- Offtake agreements

Risk: BioMCN is temporarily not able to take off the agreed volumes of biogenic CO_2 from EEW due to operational breakdown. This will lead to excess volumes of CO_2 to be dealt with by EEW.

Mitigation: Temporarily, CO_2 can be transferred to storage as intended for other EEW carbon capture plants on site. In the case of surplus, CO_2 will be emitted into the air. Off-take profiles and approaches for fluctuation adjustment will be developed and agreed with BioMCN in the off-take contract.

Risk: Available biogenic CO_2 off-take volumes are not corresponding to OCI's demand due to (temporarily) reduced availabilities or operational breakdowns for any reason (including the CO_2 pipeline). This would result in a supply gap for e-methanol production at OCI's end.

Mitigation: The remaining capture capacity at EEW destined for underground storage or the ReNabi project or further sources such as external facilities have to balance the gap temporarily. Off-take profiles and approaches for fluctuation adjustment will be developed and agreed with BioMCN in the off-take contract and framework contracts with external partners will be developed.

3.4 Market Analysis

3.4.1 Business Model

To succeed in the deployment of e-methanol (and renewable Hydrogen), the business model of HyNL relies on its ability to combine 4 effects:

- Producing products which match the to-be-adopted policies
- Delivering a comprehensive value proposal that meets expectations of potential offtakers and their emissions compliance/goals
- Reaching an acceptable business case, by leveraging on subsidies to bridge the funding gap
- Articulating a longer-term roadmap with achievable scaleup and further market developments

In the following, we will highlight successively current and future markets for the HyNL products, targeted market, value proposition and commercial strategy. The research was conducted before the crisis in the Ukraine and published in 2021: IRENA AND METHANOL INSTITUTE (2021), Innovation Outlook : Renewable Methanol, International Renewable Energy Agency, Abu Dhabi.

3.4.1.1 E-methanol market analysis

The figure here below presents the various routes and are the vision of IRENA and Methanol Institute. However it is not reflecting the official EU categorization which was not available at the time the study was performed.

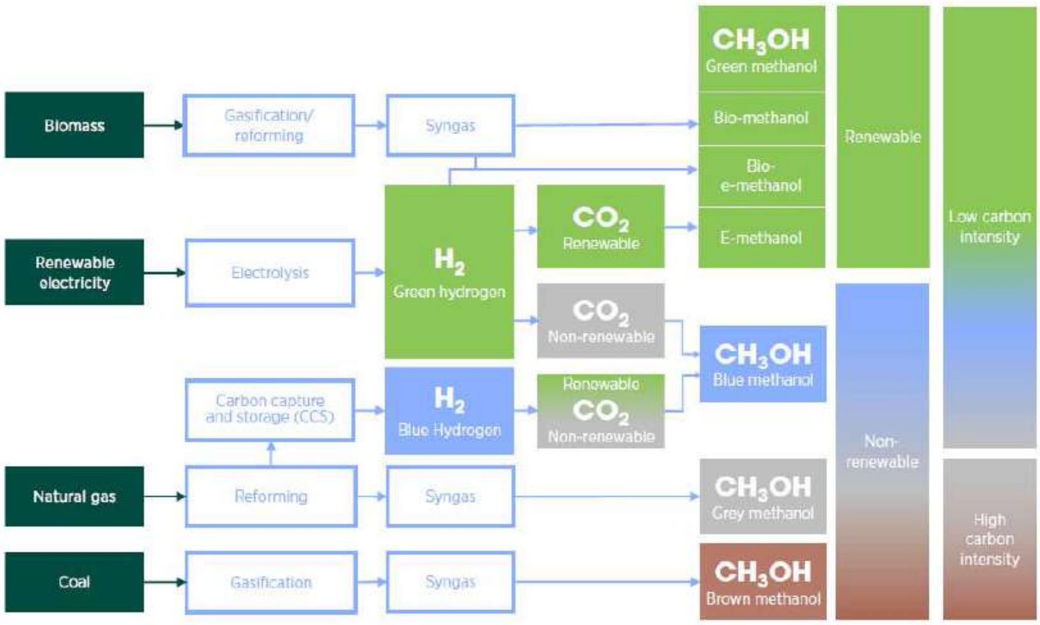


Figure 21: Principal methanol production routes

Currently, the global production of methanol is 102 Mtpa over 90 different methanol plants with a nameplate capacity of 153 Mtpa. This industry is well established and generates approximately 55 billion USD in economic activity per year. This methanol production is almost exclusively from fossil fuels, of which 35% produced from coal cracking and 65% from natural gas reforming. This is translated into yearly emissions, approximately 0.3 gigatons of CO_2 per year, corresponding to 10% of the total chemical sector emissions.

Methanol can also be made from other feedstocks that contain carbon, including biomass, biogas, waste streams and CO_2. Renewable methanol**,** as defined in the image above, can be produced using renewable energy and renewable feedstocks via two routes:

- Bio-methanol is produced from biomass
- e-methanol is obtained from CO_2 captured from renewable sources and RED2-compliant Hydrogen

It is important to note that the current EU legislation (RED2) does not refer to the source of CO_2 to be RFNBO classified. Today, less than 0.2 Mt of renewable methanol is produced annually.
In the last decade, methanol production and consumption have doubled, mostly driven by Chinese demand for gasoline blending and for methanol to olefins.

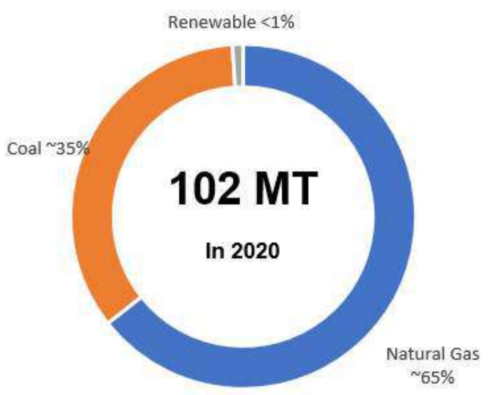


Figure 22: Source of current methanol production

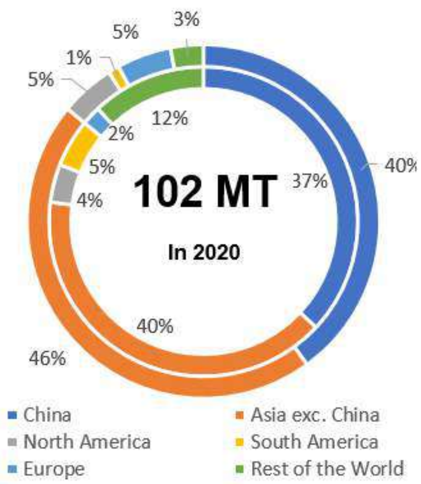


Figure 23: Methanol demand (outer circle) and supply (inside circle) by region

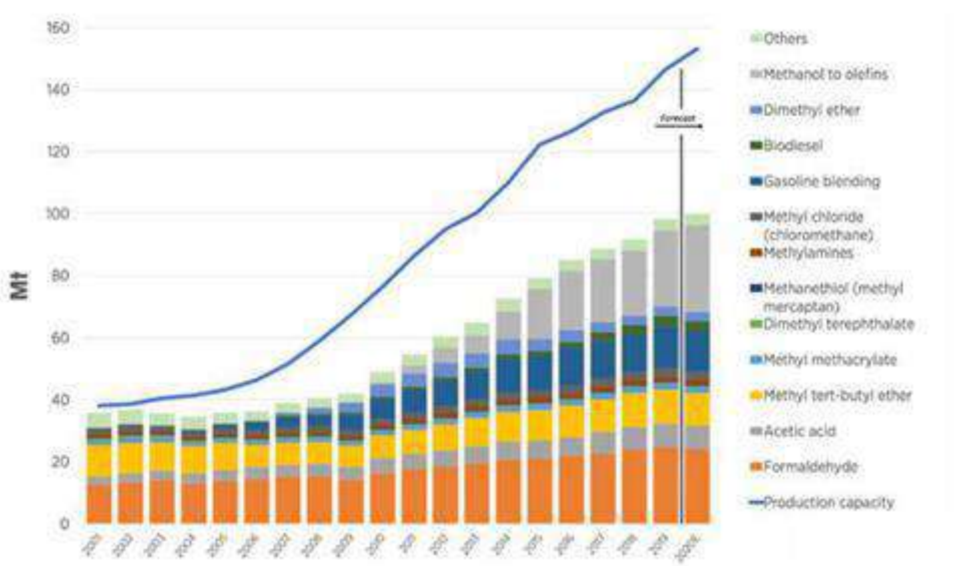


Figure 24: Increase methanol production and consumption up till 2020.

Methanol is today mainly used in the chemical industry, around 70% is used to synthesize chemicals such as formaldehyde, acetic acid, methyl and olefins via MTO (see below). These chemicals are used to produce different industrial and consumer goods, including plastics, paints, plywood, textile and car parts. When renewable methanol is used to produce plastics it offers a pathway for carbon sequestration.

In the recent years, there have been new uses of methanol, being the MTO process. The MTO is an alternative production process of ethylene, propylene, butanes and C5+ stream, together called olefins, and has seen an immense growth in the past 10 years, more specifically in China. Olefins are then converted to plastics, although other value chains for olefins exist. MTO accounts for 25% of global methanol consumption.

Methanol is currently also used as a fuel, either by itself or blended into gasoline or diesel, for the production of biodiesel or gasoline, or in the form of MTBE and DME. This type of demand has rapidly grown since mid-2000. Approximately 30% of the methanol is currently used for fuel applications, mostly in China, where methanol blending standards (up to 85%) were introduced in 2004. Biodiesel is obtained by reacting fat and oils with methanol. Direct use of methanol as a fuel, either directly or as additive for gasoline has seen a rapid growth, from less than 1% in 2020, to 14%. Methanol can be used also in modified diesel engines. The advantages of methanol in the mobility sector are that methanol does not produce soot emissions (particulate matter), fumes nor odor. In China particularly, methanol has been promoted as a transport fuel, with the main objective to decrease its dependence on imported fuel.

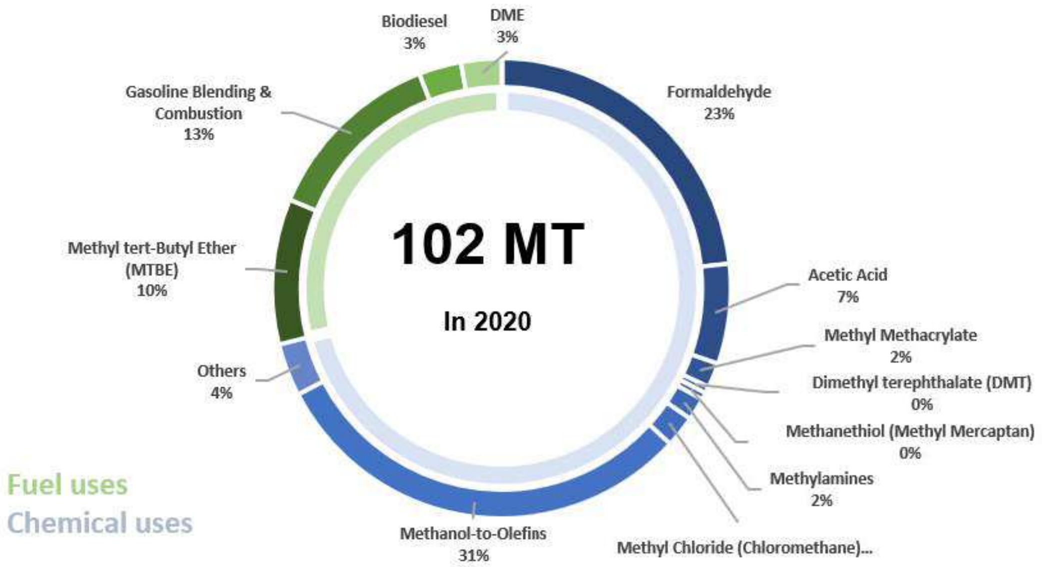


Figure 25: Global methanol demand in 2020

3.4.1.2 Export and import methanol in the EU and the Netherlands

The consumption of methanol in Europe is higher than the production. Therefore Europe imports methanol, mainly from countries with access to cheap natural gas such as Russia, Trinidad and Tobago, Norway, Egypt and the USA. In 2020 over 4,500 ktpa was imported, which corresponds to the import of the yearly methanol production of about 8 methanol plants.

The Netherlands is a net exporter, with 350 ktpa of net export in 2020. BioMCN is the largest and only methanol production facility in the Netherlands, which supports domestic EU supply of methanol. However, challenging natural gas prices have impacted the operability of the BioMCN facility currently, which has further exacerbated the EU's net import trade balance of methanol.

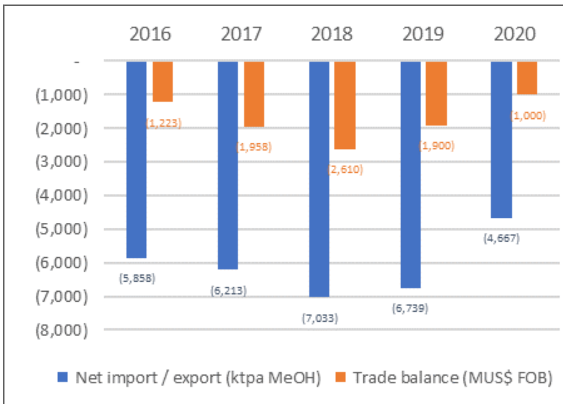


Figure 26: Trade balance of methanol in the EU-28 between 2016 and 2020.

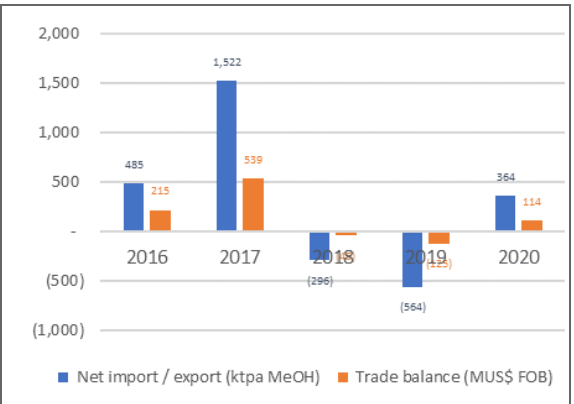


Figure 27: Trade balance of methanol in the Netherlands between 2016 and 2020.

3.4.1.3 Grey methanol price

In the past 10 years, the average spot price of methanol in Europe has been around 292 €/ton. Methanol sales are predominantly transacted either at a contract price less a specified discount or through spot market transactions. Historically, the differential between spot prices and contract prices have reflected the typical market discounts of then current contract prices. Methanol prices are highly dependent on the feedstock prices (natural gas and coal) as well as global supply and demand dynamics. Current high prices of natural gas in Europe has negatively impacted the economics of domestic producers and is not reflected in European methanol prices.

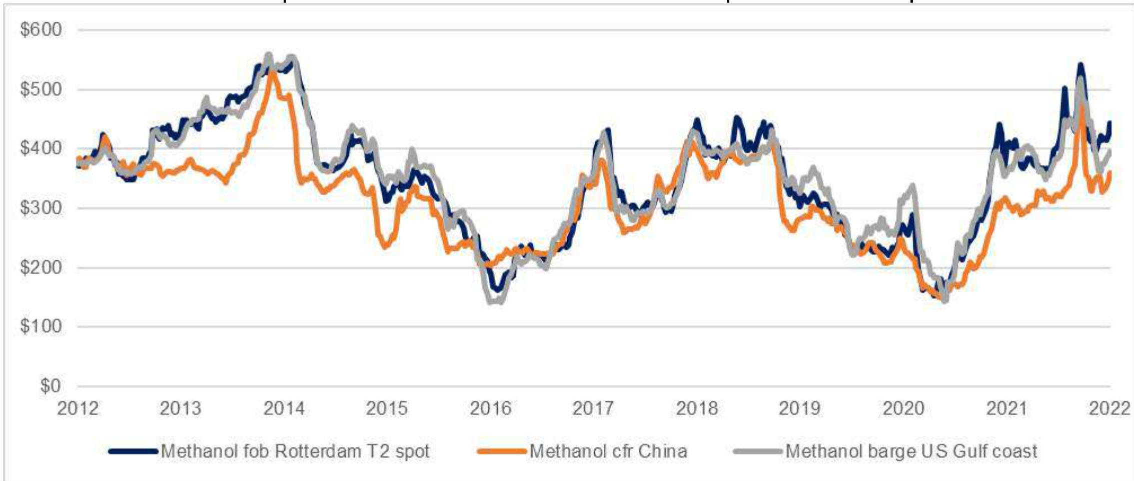


Figure 28: Grey methanol prices

3.4.1.4 Evolution of methanol market

Methanol demand growth is expected to be driven by MTO (methanol-to-olefins), traditional chemical uses such as formaldehyde and acetic acid, and fuel blending needs. Demand of methanol is expected to near 200 Mtpa by 2050, effectively doubling current demand.

The maritime transport is a sector that has shown a rapid growing interest in methanol as alternative fuel. Currently, over 20 large ships are in operation or on order that are powered by methanol.[20] Knowing that the shipping industry is responsible for 3% of total GHG emissions and 9% of GHG emissions of the transport sector, the impact of switching conventional fossil fuels in the maritime sector to alternative fuels, such as methanol provides significant demand upside for e-methanol. Depending on the source, methanol demand could be as high as 200 (without maritime demand)-310 (with maritime demand) (MMSA) to 500 Mtpa (IRENA) by 2050.

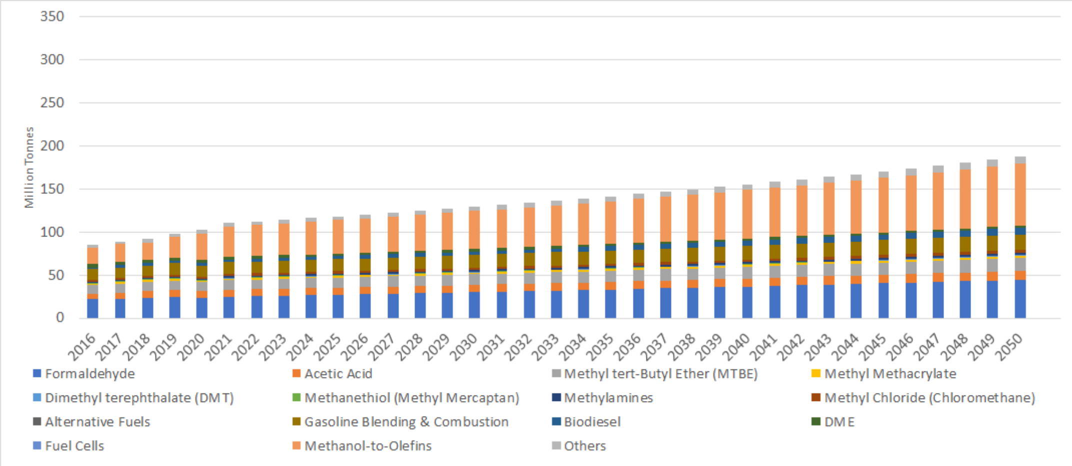


Figure 29: Methanol demand growth. Source: MMSA.

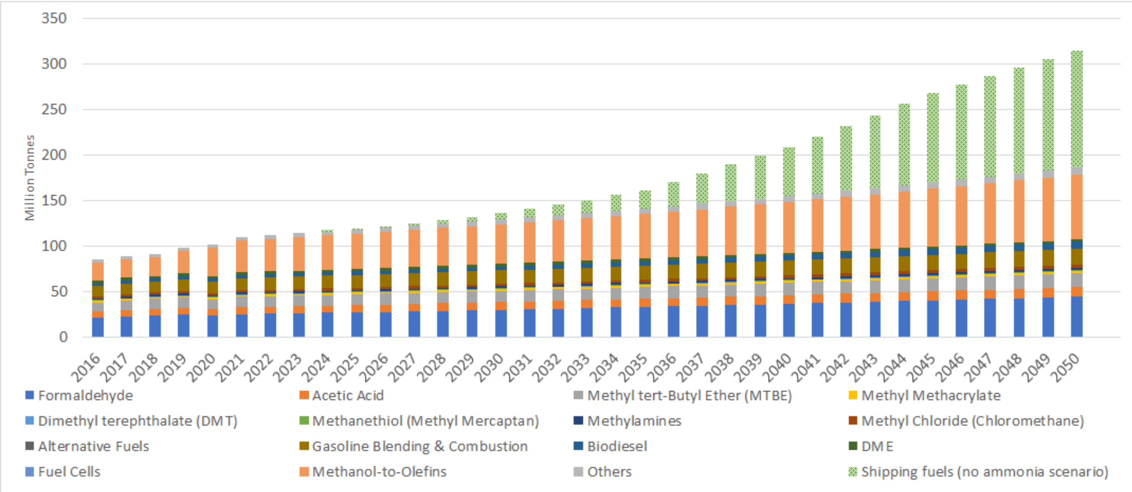


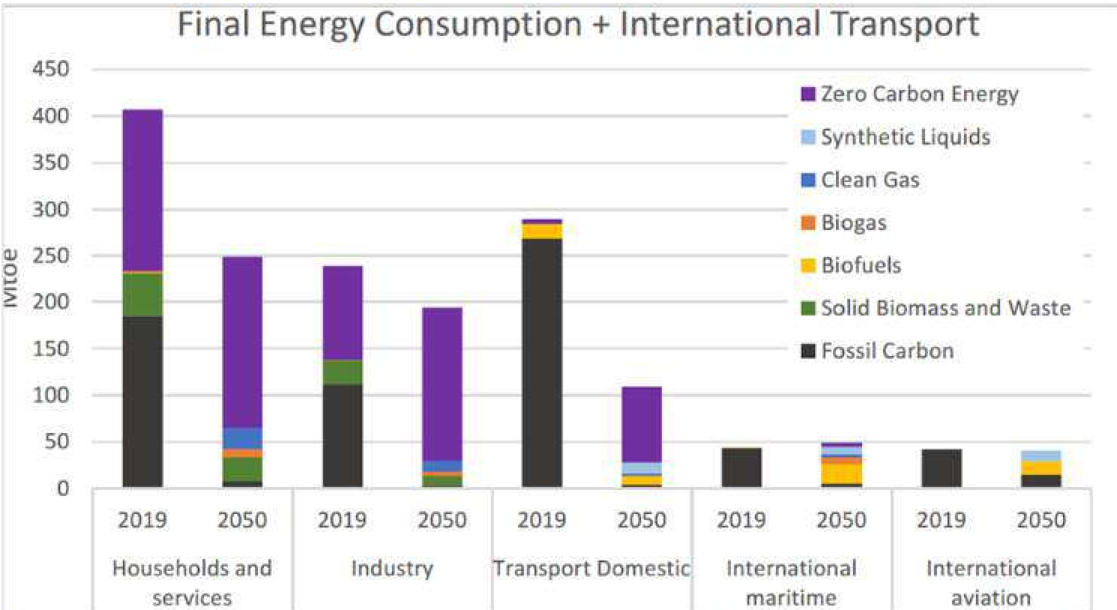
Figure 30: Methanol demand growth, including maritime if ammonia is excluded as fuel alternative. Source: MMSA & Navigate.

3.4.1.5 Expected share renewable methanol market

The introduction of renewable methanol would allow for a transition in both chemical, transport and energy related sector. However, today the higher production costs of e-methanol is a barrier for the large-scale expansion of e-methanol in the methanol market. For e-methanol to take off, demand today and in the near future needs to be stimulated by adequate policies, regulations and mandates to achieve global decarbonization. The European Union policies are evolving in this direction; the Renewable Energy Directive - RED2 mandates that 14% of the energy used in the transport sector should come from renewable sources by 2030. Therefore, the new markets for e-methanol will mainly be focused on the road transport and marine sectors where regulations will mandate the use of green alternatives to achieve decarbonization of that sector.

In the Renewable Energy Directive proposed amendment, an opportunity for renewable Hydrogen for e-methanol by 2050 is estimated at 27 TWh, corresponding to 4.3 Mt e-methanol by 2050 in the EU (~0.8 Mt H_2). This value corresponds to the Hydrogen demand for the methanol industry today. Assuming an electrolyzer load factor of 60%, this would require near 8 GW of electrolysis solely for e-methanol production, or 20% of the 40 GW electrolyzer capacity by 2030 objective of the EU. Following sectors would benefit from this e-methanol:

- Renewable methanol for the production of biodiesel
- For the blending in gasoline it could represent 2.5 Mtpa of renewable methanol across Europe in the near term (assuming that the M3 standard is implemented across the EU, meaning 3% methanol by volume in gasoline, EN 228)
- The other half would be for direct use in the transport sector, most likely the shipping industry. This is well in line with the EU's future scenario of a carbon neutral economy, assuming synthetic fuels to be a relevant type of energy carriers by 2050 substituting fossil fuels. In both scenarios, the study forecasts that almost 200 Mt of CO_2 per year will be used as feedstock for synthetic fuels. Synthetic fuels are expected to cover a substantial share of the final energy consumption in the transport sector, in domestic transport as well as in international maritime and aviation sectors (see Figure below)



Note: "Zero Carbon Energy" refers to energy forms that do not have any carbon-hydrogen bonds (electricity, heat, hydrogen); "Synthetic Liquids" refer to liquid fuels produced from carbon-free hydrogen and carbon atoms; "Clean Gas" refers to methane from carbon-free hydrogen and carbon atoms.

Source: 2019: Eurostat; 2050: PRIMES model

Figure 31: Evolution Final energy consumption.

IRENA estimates that by 2050, 250 Mt of e-methanol and 135 Mt of bio-methanol will be produced annually globally. This is an extreme scenario that would result in the need of 406 GW of electrolysis globally for the e-methanol production.

E-methanol will have to depend on access to carbon-zero CO_2 to be considered 100% renewable methanol. This CO_2 can be sourced from bioenergy carbon capture processes or from Direct Air Capture (DAC), however the latter is very cost prohibitive today. It should be noted that carbon capture with CO_2 transport by ship back to e-methanol production is also being developed by shipping companies believing in the need for CO_2 to ensure massification of the energy content.

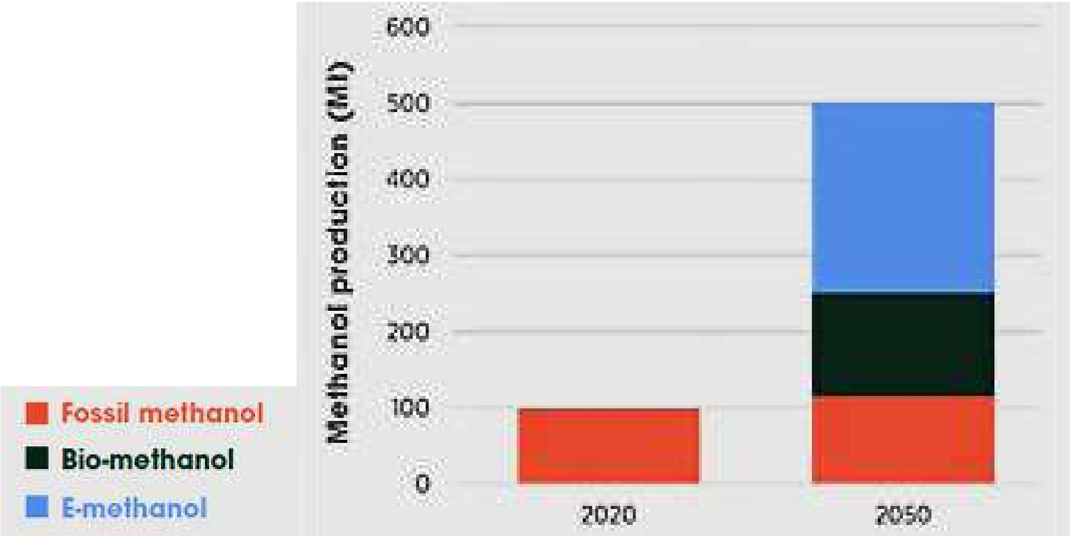


Figure 32: Evolution methanol production by 2050 and share of methanol types.

3.4.1.6 E-methanol in the maritime sector

As the International Maritime Organization (IMO) has committed to reduce CO_2 emissions by 50% by 2050, alternative low-carbon fuels such as e-methanol and ammonia will be crucial to reach such objectives.

Key players in the maritime sector are showing growing interest in methanol. In 2015, Stena Line retrofitted to the Stena Germanica, a ferry operating between Germany and Sweden, in less than 3 months to run its 4 stroke diesel engine on methanol. In 2016, Methanex converted the 2 stroke diesel engine to run on methanol of one of its methanol tanker. Since then, methanol tankers have spearheaded the adoption of methanol as a shipping fuel but other companies are now devoting resources for the adoption of renewable methanol in newbuilds. Maersk ordered a feeder container ship fueled by methanol in February 2021 as a pilot project. Confident that the technology is mature, in August 2021 it ordered 8 large container vessel capable of running on renewable methanol, to be delivered between 2023 and 2024 and confirmed 4 options of the same vessel type in January 2021. Other companies have followed, such as Xpress Feeders, a Singaporean company, who announced the order of 8 small container vessels using methanol as a fuel in November 2021. Van Oord, a Dutch dredging and maritime work company also ordered its first wind offshore turbines installation vessel operating on methanol in October 2021. In 2021, OCI signed partnership agreement with MAN Energy Solutions and Eastern Pacific Shipping to charter the first retrofitted methanol fueled vessel.

Due to the expansion of the maritime transport sector, maritime fuel market in HFO equivalent could be as high as ~430 Mt by 2050 (vs ~340 Mt in 2020). The total theoretical potential if all this demand switch to methanol is as high as ~700 Mt.

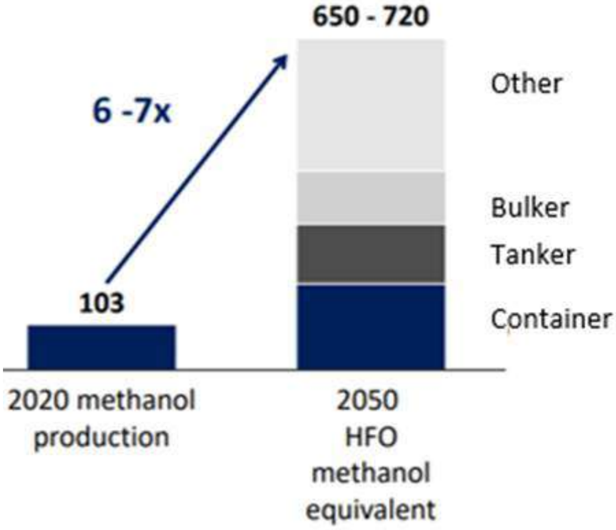


Figure 33: OCI, ESG Strategy investor day, March 2021

The future demand of renewable fuels from the shipping sector will be highly dependent on regulations imposing carbon levy or mandating the adoption of low carbon alternatives to conventional maritime fuels. The growth of the maritime transport sector, estimated between 50 to 250% by 2050 depending on the forecasts and the strengthening of energy efficiency requirements will also have a large impact on the final demand for renewable fuels such as methanol.

IRENA has published a 1.5°C scenario pathway, with a conservative 56% increase of the maritime sector activity between 2018 and 2050 and a significant improvement of energy intensity levels. In this conservative scenario regarding energy demand in the maritime sector, a 70% renewable share of the fuel consumption of the shipping sector is reached, with a limited participation of LNG.

The e-methanol represents near 10% of the total energy demand of the shipping sector by 2050. This represents a yearly demand of 40 Mtpa of e-methanol for shipping, which is more than one third of current methanol production. In addition, 9% of the energy demand for shipping in 2050 is expected to come from advanced biofuels, a category that include bio-methanol.

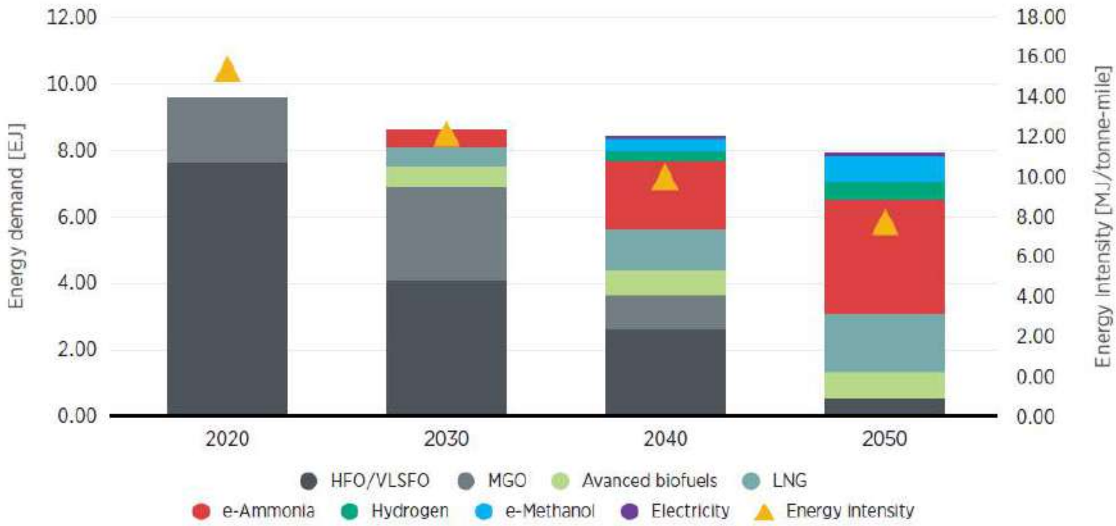


Figure 34: Final energy demand of sea going shipping sector between 2020 and 2050 in the <1.5°c pathway (note: “advanced biofuels” includes bio-methanol)

In 2018, the marine fuel consumption reported in the EU-MRV system was 44 Mt. This represents about 13% of the global marine fuel consumption, estimated at 339 Mt. Therefore, in the EU we can estimate that there is a minimum yearly demand of 5 Mtpa of renewable methanol for shipping by 2050.

Measures proposed in the FIT for 55 Package could help bridge the competitiveness gap between conventional maritime fuels and renewable fuels, including renewable methanol.

The Fuel EU Maritime initiative, proposes a common EU regulatory framework to increase the share of renewable and low-carbon fuels used in the EEA by mandating a reduction of carbon intensity of shipping fuel but it would not require operators to use specific fuels. Minimum penalties for noncompliance are set at 2400 EUR/t of fuel (VLSOF) (~210 €/MWh).

Figure 35: maritime targets on the limits on greenhouse gas intensity of the energy used on-board compared to 2020

Other proposed rules envisioned the inclusion of the maritime sector in the EU emissions trading system and the taxation of conventional maritime fuels. These propositions could fast-track the adoption of renewable maritime fuels in the EU and push their share above the worldwide trend.

3.4.1.7 Current and future production costs renewable methanol

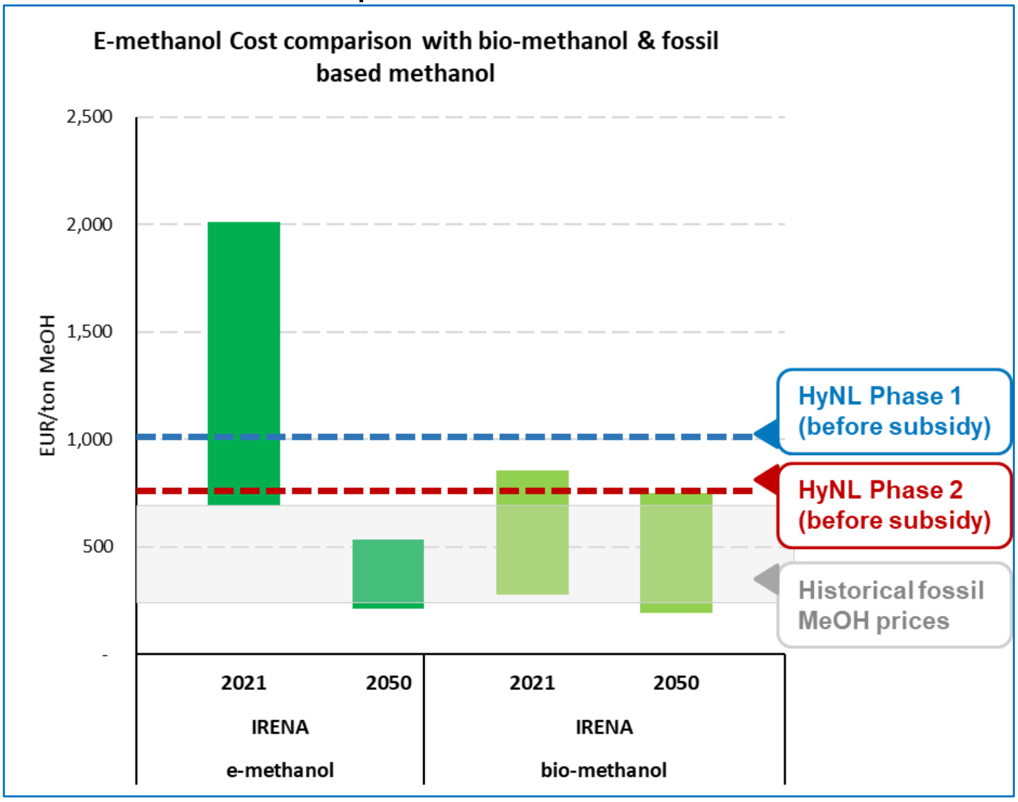


Figure 36: HyNetherlands e-methanol will reach competitiveness on the long-term with fossil based methanol and bio-methanol. Source: IRENA.

The production costs of renewable methanol are dependent on the following:

- For bio-methanol on the access to biogas or biomass feedstock and related costs
- For e-methanol, costs depend on:
  - The cost of Renewable Hydrogen, which depends on the electrolyzer CAPEX and renewable electricity costs
  - The access and source of renewable biogenic CO_2 source or DAC:
  - Carbon Capture and utilization (CCU), this process involves the direct capture of CO_2 during industrial processes where biogenic CO_2 is released, such as for waste-to-energy plants, biomass-to-electricity units and methanisation units. This is the cheapest renewable CO_2 source. Today, the CO_2 cost ranges from 50-100 €/ton for industrial and biogenic sources, but could fall below 50 €/ton for carbon sources with high CO_2 concentrations. On the long-term, another source of CO_2 is through direct air capture technologies (DAC). DAC costs are still very high today (300-600 USD/ton CO_2), but are expected to decrease below 50 USD/ton by 2050.

An analysis of IRENA shows the evolution of e-methanol and bio-methanol production costs and compared to past methanol prices, as well as compared to the HyNL e-methanol cost (before subsidy) for phase 1 and 2.

3.4.2 Scalability

The HyNetherlands (HyNL) project is a kick-off project to trigger the deployment of H_2, carbon capture (CC) and e-methanol production on a large-scale basis in Europe. The HyNL project will be coupling at least 7 sectors: (i) the renewable power enables production of (ii) Hydrogen, which is transported and stored through (iii) Hydrogen Infrastructure to enable the production of (iv) e-methanol using biogenic CO_2 from (v) a waste-to-energy (W2E) plant to decarbonize (vi) maritime applications. In addition, HyNL will also feed renewable Hydrogen into (vii) Mobility sector and other industries.
The HyNL project partners have each defined concrete plans to further expand the project at the current location. These plans are detailed below:

3.4.2.1 Expansion at the project sites

- **ENGIE**

ENGIE has defined a long-term H_2 roadmap for future expansion of the electrolysis capacity at the Eemshaven project site. The 100 MWe ENGIE H_2 plant in HyNL has the objective to be a fast-track large-scale demonstration project to trigger the H_2 market in the region, and to demonstrate the bankability, scalability and replicability potential at the site, region and throughout EU. The first H_2 uses will focus on the refinery sector (e-methanol for maritime applications) and to H2 for mobility. The objective of the ENGIE H_2 roadmap is to reach 850 MWe by 2030 and 1.85 GWe by early 2030´s, reaching over 200 ktpa H_2 production, with a diversity of usage from chemical sector to mobility to steel industry and others. Within the ENGIE Hydrogen roadmap, the renewable H_2 consumption for e-methanol production represents less than 20% of the final renewable H_2 production. The ENGIE Hydrogen roadmap (up to phase 3 in Figure 1) will avoid nearly 3 $MtCO_2eq$ per year.

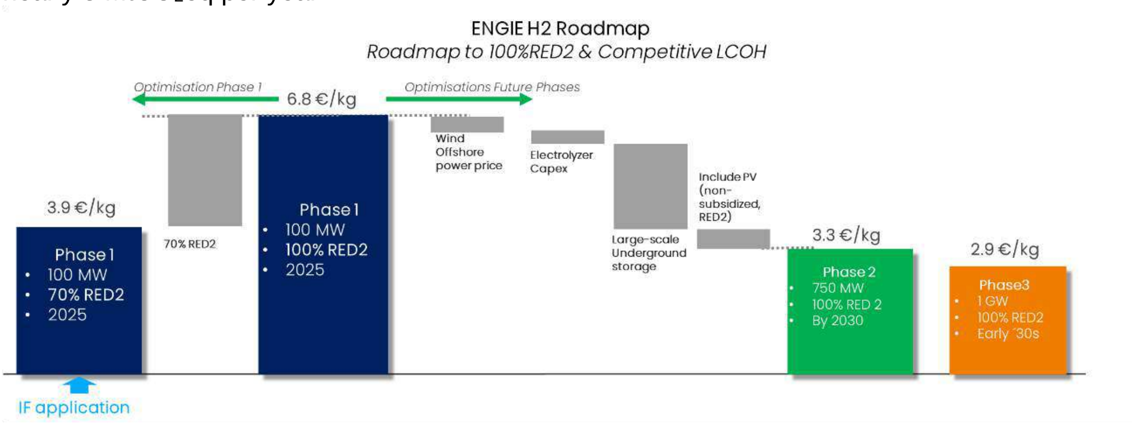


Figure 37: ENGIE H_2 roadmap and related LCOH cost reduction and levers to reach for phase 2.

The ENGIE Hydrogen roadmap represents only a part of the potential renewable H_2 production in The Netherlands, as presented in the Section on 'Economy-wide Impact'.

Technology transfer**:** The objective is to achieve with HyNL a scalable and replicable design of the H_2 plant to be deployed across EU, incl. the renewable electricity sourcing strategy and integration with other CC projects. This would fit with the objective of ENGIE to develop 4 GWe of renewable H_2 production capacity world-wide by 2030. HyNL will allow ENGIE, its partners and electrolyzer manufacturers to learn from previous phases and contribute to improved electrolyzer plant design for all future renewable H_2 projects, and meet and have contributed to the development of anticipated industry standards. In addition, the ENGIE Hydrogen roadmap onboards market and financial stakeholders to ensure investment risk management.

- **EEW**

EEW runs today three waste incineration lines in Delfzijl and will further expand with a fourth line by 2024. Based on calculations according to specifications by the National Emissions Authority (NEA), about 61% of the 583 ktpa CO_2 emissions at the Delfzijl W2E plant are of biogenic origin. After addition of the fourth line, this share is expected to increase to 63% of 607 ktpa CO_2 emissions. By 2030, EEW plans to equip all lines with carbon capture units:

- By 2025, EEW will install two 100 ktpa carbon capture units at lines 2 and 3, thereby providing around 122 ktpa biogenic CO_2. About 100 ktpa of this biogenic CO_2 will be provided to BioMCN, of which 77.5 ktpa within this HyNetherlands project's scope.
- By 2030, EEW intends to add two more carbon capture units to lines 1 and 4 (capacity of 200 ktpa CO_2, of which at least 125 ktpa of biogenic origin). *This* CO_2 *could be provided to BioMCN for the scale-up of their e-methanol production.*

Technology transfer: In total, EEW runs 17 W2E plants (one in Luxemburg and 15 plants in Germany). Based on experiences in this project, EEW intends to install large-scale carbon capture plants at least at three other sites by 2030 (plants located in Stapelfeld, Magdeburg and Helmstedt). This would mean an additional carbon capture capacity of 1.2 Mtpa. In the long run, carbon capture units can be installed at all sites, equivalent to a potential of 5 Mtpa of carbon capturing.
Carbon capture technology can be transferred to all remaining CO_2 *emitters in the Netherlands (and European-wide). This includes in The Netherlands 12 W2E plants, equivalent to ~7 Mtpa* CO_2 *(~60% biogenic). Further possible industries where CC units could be installed are the biomass sector and hard-to-abate industrial sectors, such as cement and steel production.*

- **OCI**

OCI has today a production capacity of 1000 ktpa methanol at the Delfzijl plant, of which between 4-8% bio-methanol production (depending on the methanol market demand and plant economics). OCI is planning a second phase to further expand the e-methanol production at the project site with an additional 100 ktpa e-methanol (equivalent to ~180 MWe electrolysis), replacing existing grey methanol production. If we assume similar CO_2 sources, we estimate the GHG emissions avoidance w.r.t. the e-methanol to reach an additional ~140 $ktCO_{2eq}$ avoided per year.

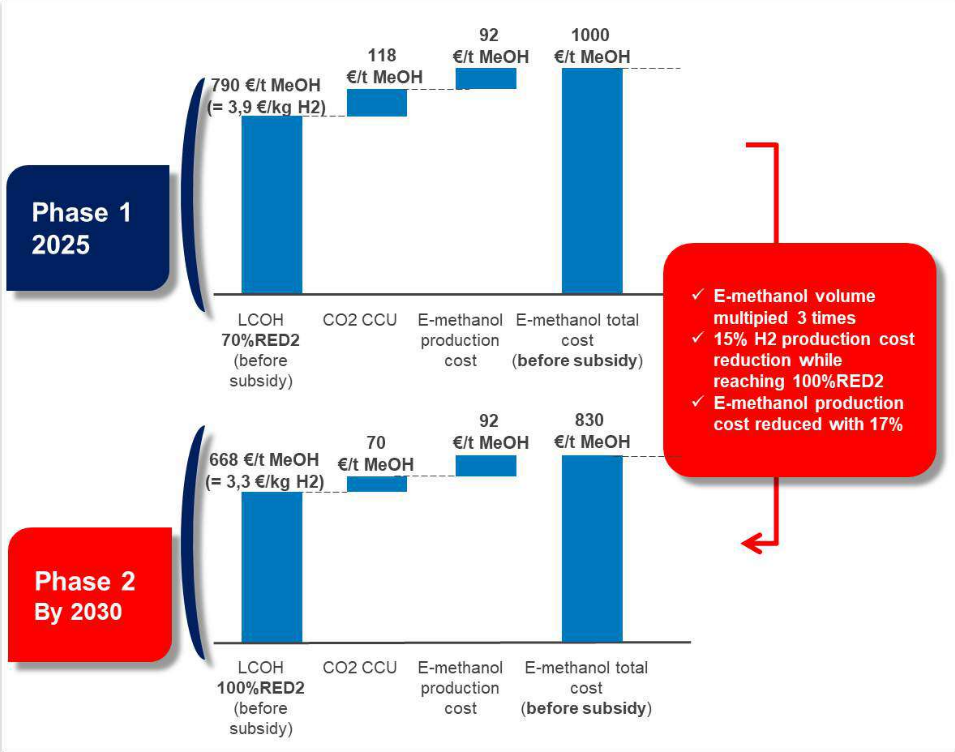


Figure 38: Cost development e-methanol

Technology transfer: The HyNetherlands project will give the required technical expertise to scale-up the e-methanol production in the second phase with an additional 100 ktpa.

OCI could scale up to 25% e-methanol with no signification CAPEX impact. To reach 100% e-methanol in the long run (equivalent to a yearly consumption of 1.2 $MtCO_2$ and 170 kton H_2) it will require significant CAPEX to modify the BioMCN plant equipment and utilities as less steam will be available from the un-used reformer (e.g. new e-driven compressors, new e-motors to circulate the synthesis gas in the synthesis loop, new reboilers for two distillations columns, State-Of-The-Art energy savings solutions, etc.).

3.4.2.2 Cooperation with other actors of the regional economy

The three facilities are all located in the same region in the North of the Netherlands. HyNL project will cooperate with several actors of the regional economy and thus trigger further activities in the region:

- Gasunie will implement phase I of its anticipated H_2 transport network in the northern region (HyNetwork Services) and the HyNL project is one of the first users, justifying the investment in the northern H_2 backbone. Hynetwork and HyNL work closely together to assure a smooth and replicable implementation of interfaces, metering and contracts for producers and offtakers. This network will connect to the large-scale underground storage of Hystock in later phases. The interest was expressed to make use of Hystock during Phase I-III of the ENGIE H_2 roadmap.
- Groningen Seaports (GSP) is the economic operator, developer and authority for the port of Delfzijl, Eemshaven and the adjoining industrial sites. As part of its port services, GSP aims to facilitate circularity within the industrial estates and has committed to develop a CO_2 connection (~1.9 km) between the EEW and the BioMCN project site. Other CO_2 offtakers in the region could be connected in the future (e.g. Lubrizol, Photenol, SkyNRG, Avantium, ChemCom or Nobian).
- Universities: ENGIE will enter into collaboration with TU Delft and University of Groningen, with whom a LoI has been signed. With TU Delft, a PhD will be funded to isolate and study phenomena of interest in a small scale lab set-up, including intermittent behavior, and to perform data analysis on the actual operational performance data. With University of Groningen, a post-doc project will be started to study the regional H_2 mobility market, as well as the market of the electrolyzer by-product (oxygen and waste heat) in The Netherlands.

3.4.2.3 Impact on the regional economy

The HyNL project and the implementation of each consortium partner's roadmap for future expansion will have an important impact at the regional economy and employment. The HyNL project development involves around 180 M€ of direct investments (excluding investments in offshore wind and infrastructure on Hydrogen pipeline and underground storage). The future upscaling of each Consortium partners' roadmap will require an additional investment of nearly 2 billion €.

The HyNL project is key to kickstart the e-fuels and H_2 economy in The Netherlands and Europe, as the produced e-methanol will be a RFNBO (renewable fuel of non-biological origin). HyNL will develop large-scale e-fuels and H_2 chains that will enable the creation of a renewable Hydrogen and RFNBO market in Europe, thanks to the roadmap with high technology cost reductions (see scalability at sector level); hence to make large-scale H_2 and e-methanol production more competitive.

As outlined in the Dutch Climate Agreement[4], the project and future scale-up perfectly fit with the Dutch H_2 roadmap (500 MWe by 2025 and 4GWe by 2030 of electrolyzer capacity) and European H_2 roadmaps (40 GWe by 2030), while at the same time:

- reinforcing the methanol industry in The Netherlands by switching from fossil-based processes to renewable-based e-methanol production, and thereby reducing the dependence on import of fossil fuels;
- capturing and using biogenic CO_2 from W2E plants to reduce emissions and contribute to circularity.
- Developing a renewable Hydrogen auctioning. Besides its innovative character, this auctioning will provide access to renewable and/or RED2 compliant Hydrogen volumes to different potential offtakers

3.4.2.4 Impact on regional employment

The HyNL project will also secure local anchoring of knowledge and expertise, and thereby will result for each consortium partner's scope in an important impact on the regional employment.

- **ENGIE**

A successful project would result in the following jobs at the project site:

- Development phase**:** 3 direct FTE (Project manager, Technical Team) and 15 indirect FTE (Public affairs, stakeholder management, H_2 design architects, legal, procurement, consultants)
- Installation phase**:** 38 FTE directly or indirectly involved from ENGIE (e.g., project director, project manager, technical manager, contract manager, project engineers, supporting functions, Owners Engineer) and 250 FTE (estimation) through subcontracting over a period of 24-30 months.
- Operations & maintenance**:** An estimated addition of 10 FTE to the existing operational organization (operators, engineers or technicians and an extra position in the HSSE and Quality management teams). On longer term (foreseen after 2030), the project will create job retention for at least 18 direct FTE (structural jobs) and 30 indirect FTE when the ENGIE Eems power plant will be decommissioned.

On top, the project will have a positive impact on the employment in the complete H_2 value chain (renewable electricity, H_2 production, midstream and downstream applications), incl. employment in R&D, manufacturing, construction, infrastructure, etc. For the HyNL ENGIE Hydrogen roadmap, it is estimated that the implementation of 1.85 GWe could result in more than 3,000 jobs in sectors related to electrolyzer and renewables, and more than 7,000 jobs in the complete renewable H_2 value chain (recurrent and on-off jobs), considering the Groningen gas phase-out, renewable Hydrogen in the Netherlands and specifically the North of the Netherlands will promote

[4] https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/klimaatakkoord

the reorientation of qualified personnel, as the Hydrogen will keep the current natural gas pipelines in use thanks to its refurbishment to Hydrogen pipelines.

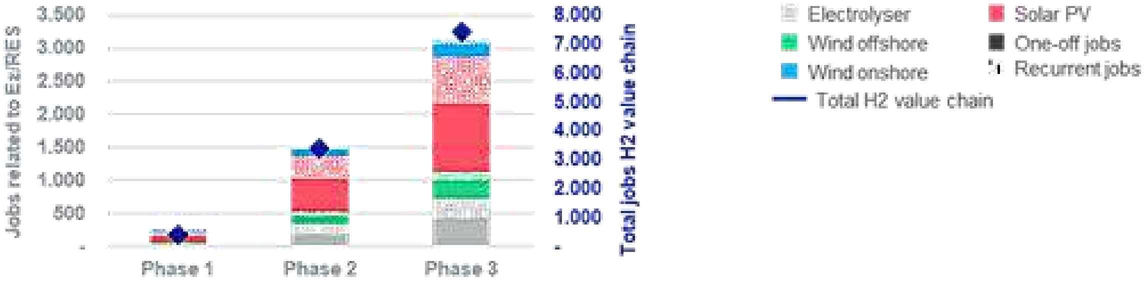


Figure 39: Impact on employment (one-off and recurrent jobs) of the HyNL scale-up roadmap of ENGIE (1.85 GWe by 2030).

- **EEW**

EEW employs 79 FTE at their W2E plant. The carbon capture plant will be operated from the central control room of the W2E plant, mainly by the existing staff. The following jobs will be created:

– Development and implementation phase**:** 5-7 direct FTE from EEW (Project manager, Technical Team, of which 4 to 5 people on location), and subcontracting for civil activities (15-20 people per day during 3 months) and from the technology supplier (30-50 people per day during 15 months).

– Operation and maintenance: of the carbon capture plant: one additional chemical engineer will be employed.

- **OCI**

OCI employs about 95 FTE at the BioMCN project site. A successful execution of the project facilitating the further expansion of renewable H_2 consumption, will help securing these jobs in The Netherlands. Without the project (hence no production of e-methanol), the future of the site would be significantly impacted by upcoming regulations (such as EU ETS system, Dutch CO_2 taxes), meaning the (grey) methanol production would not be financially sustainable in the medium to long term. The project will also temporarily increase the indirect employment during construction (2 FTE for local contractors/suppliers).

3.4.2.5 Sector impact

The HyNL project will be the first demonstration project to trigger the renewable H_2, carbon capture and e-methanol deployment at large-scale in The Netherlands. If successful, the project will be unique in terms of upscaling and replicability for other H_2 offtakers in the region, and other e-methanol plants in Europe. The replication could take place in other regions in Europe with an availability of both low cost renewable energy (to produce competitive renewable H_2) and carbon sources. At short to mid-term, the carbon source could be– but not limited to – (i) biogenic CO_2 captured from W2E plants, (ii) biogas production, (iii) hard-to-abate sectors with unavoidable CO_2 emissions. In the long-run, as a result of high cost reductions, CO_2 from direct air capture will be a potential additional CO_2 source. *On the long-term, the development of Hydrogen and* CO_2 *backbones will further facilitate the sector scalability, as locations for Hydrogen production, carbon capture and carbon use could be decoupled to locations with optimal renewable conditions, suitable* CO_2 *sources, etc.*

As described in the previous section on project scalability, the technology developed in the HyNL project can be easily transferred to the whole sector of methanol production (~4 Mtpa methanol production capacity in Europe) and other molecules based on reforming technology (e.g. ammonia[5], synthetic kerosene…), for both brownfield and greenfield projects. As technology will be de-risked and technology costs will reduce, further upscaling of plants will be possible. All data and expertise gathered in the project (e.g. operations and functioning of the plants) could be adopted in existing and future plants of the project partners. There are no barriers regarding IP management, since all technologies will be available from various suppliers, and pipelines will be publicly accessible.

In general for all technologies in the HyNL project (renewable Hydrogen production, carbon capture and use applications), the key barrier for Europe-wide application are of economic nature. So far, there is no market existing and the legal framework has not been established (e.g. EU Carbon Removal Certification System). However, with a large potential e-methanol market, the HyNL project will lead to creating better market conditions by pushing cost reductions and establishing market structures that other e-fuels and renewable Hydrogen projects could build upon.

3.4.2.6 Potential e-methanol market

Today, the global production of methanol is 102 Mtpa, which is almost exclusively produced from fossil fuels (~35% from coal cracking and ~65% from natural gas reforming, <1% from biomethane). The EU is a main importer of methanol, importing in average 6 Mtpa.[6] In the EU, production is mainly located in Germany, The Netherlands, amounting to an annual production capacity of ~4 Mtpa (largely produced from natural gas). Methanol demand growth is expected to be driven by traditional chemical uses, fuel blending needs and the maritime sector. The maritime transport is a sector that has shown a rapidly growing interest in methanol as alternative fuel, with an expected methanol demand up to 310 - 500 Mtpa by 2050. E-methanol has significant potential as a renewable marine fuel, displacing fossil marine gas oil and diesel and thus reducing CO_2 emissions in shipping.

In the Renewable Energy Directive amendment, the market potential of renewable Hydrogen for e-methanol production is estimated at 27 TWh, corresponding to approximately 4 Mtpa e-methanol by 2050 in the EU (~0.8 Mtpa H_2corresponding the annual Methanol production in

Europe. Assuming an electrolyzer load factor of 60%, this would require around 8 GW of electrolysis solely for e-methanol production.

3.4.2.7 Expected contribution to GHG emissions avoidance at sector level

The HyNL project will be the first large scale industrial demonstrator of e-methanol production based on renewable Hydrogen and biogenic CO_2 captured from a W2E site. HyNL can be replicated to other brownfield methanol units and W2E sites in Europe. An analysis was performed on existing methanol production units in Europe and nearby W2E sites (<20 km from methanol production unit) to identify potential e-methanol volumes with similar design principles as HyNL. All regions with large-scale methanol production units and nearby W2E units, have good renewable potential (wind) to produce renewable H_2, as HyNL.

Country		City	Capacity (ktpa MeOH)	W2E nearby (ktpa waste)	CO2 potential W2E (biogenic) (ktpa CO2e)	Max e-MeOH (ktpa e-MeOH)
Germany		Leuna	700	728	364	262
Germany		Ludwigshafen	480	900	451	325
Germany		Gelsenkirchen	300	2045	1025	300
Germany		Wesseling	250	1365	684	250
Netherlands		Delfzijl	1000	576	356	257
Norway		Nordmøre	900	30	150	108
Total			**3530**	**5644**	**2829**	**1360**

Table 40: Main Methanol production capacity in Europe.

Excluding the methanol unit in Delfzijl (part of HyNL), the replication of the HyNL project across the sector in Europe could reach 2.3 Mt avoided GHG per year (see sheet “Scalability” in the GHG emission avoidance calculations excel for details on calculations and sources used). This analysis excludes potential upsides of other biogenic CO_2 sources, such as from bioethanol, biogas, paper and pulp or DAC capture units.

3.4.2.8 Expected cost reductions and resource constraints

E-methanol and renewable Hydrogen production today are not cost-competitive yet with other low-carbon alternatives (e.g. bio-methanol or blue H_2). However, as technology is replicated, scaled, demonstrated and de-risked, major technology cost reductions are expected resulting from technology improvements and economies of scale.

While methanol synthesis is a mature technology and no large cost reductions are expected, the e-methanol production cost is mainly dependent on the cost of renewable electricity, renewable H_2, and CO_2. Therefore, kickstarting the H_2 and CCU economy today with first large scale demonstration plants is necessary and will allow to scale up renewable electricity, electrolysis capacity and carbon capture technologies. This will allow to achieve the necessary cost reductions, resulting in e-methanol production cost reductions, comparing future renewable methanol production cost to fossil methanol.

In this perspective, an internal ENGIE study has demonstrated that considering strong technology cost reductions, starting in 2030 local renewable H_2 production would become competitive with blue H_2 in The Netherlands. Moreover, a renewable H_2 rich scenario would be the lowest- cost scenario to fully decarbonize the industry by 2050, saving around 867 M€$_{2021}$ per year compared to a scenario where the energy transition in The Netherlands would mostly rely on electricity as final energy vector (or only blue H_2). In a scenario where all methanol in The Netherlands would be produced with renewable H_2, the total cost would be ~250 M€$_{2021}$/year cheaper (by 2050) compared to a scenario where majority of the methanol production would be based on CCS.

- **Electrolyzer**

Electrolyzers today are most vulnerable on two different levels, (i) the high investments required today and in the near future, and (ii) the still limited manufacturing capacity for most electrolyser suppliers. As presented in different public reports, important cost reductions and efficiency improvements are expected thanks to massive electrolyzer deployment. HyNL will contribute to this, as it is a clear implementation example of large-scale first-of-its-kind flexible electrolyzer, that will improve stack design, efficiency, increase module size and ability to run on intermittent power, which is key for RED2 compliant Hydrogen. The renewable H_2 production cost (LCOH) is expected to strongly reduce between now and 2050, as illustrated.

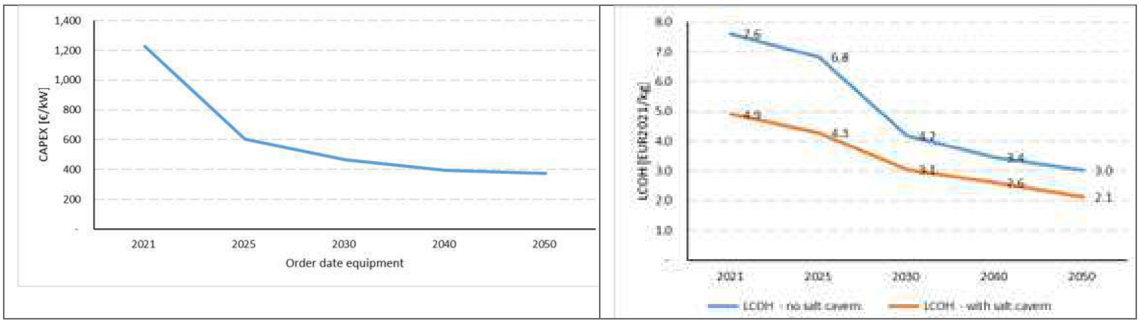


Figure 41: Expected cost reductions for alkaline electrolyzers (IEA) and the resulting impact on LCOH (own calculation).

The price of renewable H_2 is driven by (i) the cost of electricity (see next section), (ii) the cost (and efficiency) of the Hydrogen plant and (iii) the operation regime (e.g., operating near-baseload would decrease the cost of H_2). Moreover, as presented, the availability of a low-cost underground storage (e.g. salt cavern), has an important positive impact on the LCOH.

- **Renewable electricity cost and resource constraints**

The availability of cheap renewable electricity is key to produce low-cost renewable Hydrogen. As presented, strong reductions in levelized cost of electricity from offshore wind is expected, requiring (i) technology cost reductions of offshore wind turbine technology, and (ii) increase in capacity factors (e.g., due to technology improvements). HyNL electricity supply is planned to be supplied through a wind-offshore PPA, which is below the average LCOE for wind offshore forecast of IEA.

The production of H_2, e-methanol and other e-molecules (chemical sector) will require large amounts of low-carbon and renewable electricity, which could be a major resource constraint. For The Netherlands, an internal ENGIE study. on the role of renewable H_2 in The Netherlands (see also Section on 'Economy-wide Impact') has indicated that the technical potential of renewable electricity production exceeds the renewable electricity needs to cover the electricity demand for renewable H_2 production and other electricity demand (industrial, commercial, residential and mobility).

When developing renewable Hydrogen and CCU projects, it is also key to note that the electrolyzer deployment will facilitate the further integration of renewable electricity sources in the power system, while avoiding grid congestion. The ENGIE study has also indicated that a massive upscaling of electrolysis capacity to decarbonize the energy system by 2050 will facilitate the integration of renewables in the system and minimize the curtailment of renewables, whereas in a blue H_2 -only scenario (SMR + CCS) the relative curtailment is more than two times higher.

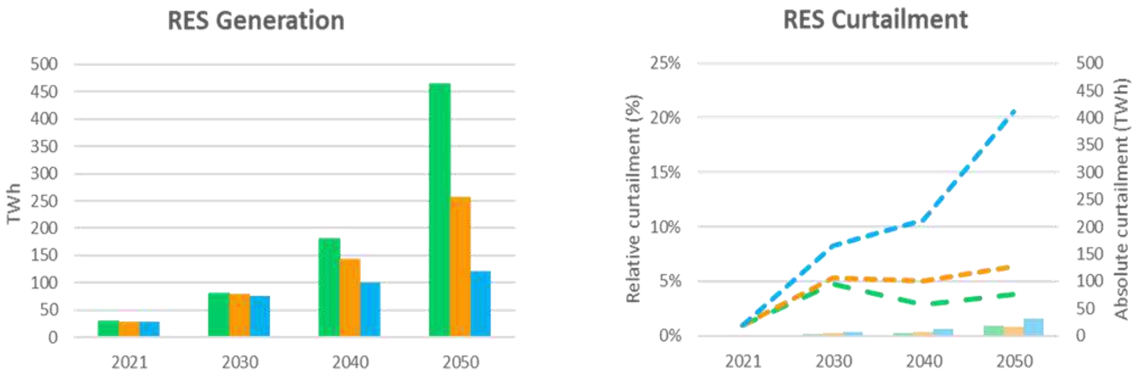


Figure 42: Impact on renewable electricity production,

*RES curtailment in The Netherlands for 2 scenarios relying on large-scale Hydrogen deployment (**mix renewable-blue** H_2 vs. **solely blue H_2**) and 1 scenario mainly relying on **electricity** to reach a decarbonized energy system in The Netherlands by 2050.*

- **Carbon capture technologies**

The cost of CO_2 is dependent on the source of CO_2, the CO_2 concentration, and capturing technology. Due to a lack of progress in deploying CCU applications to date, many technologies and applications are still at an early stage of commercialization. Therefore, there is an important potential for cost reductions for different carbon capture technologies. Different market observants expect that costs will significantly decrease. Today, the CO_2 cost ranges from 50-100 €/ton for industrial and biogenic sources, but could fall below 50 €/ton for carbon sources with high CO_2 concentrations. On the long-term, another source of CO_2 is through direct air capture technologies (DAC). DAC costs are still very high today (300-600 USD/ton CO_2), but are expected to decrease below 50 USD/ton by 2050. Realizing this cost reduction potential will require strengthened policy support to drive CCUS innovation and deployment.

By making large-scale utilization of carbon capture possible at a W2E plant, this project will contribute to generating cost reduction potential. Costs for carbon capture from W2E plants are mainly driven by feedstock costs. Therefore, this project has a strong focus on realizing energy demand reduction potential in the course of the project. For the first project phase, proven technology was chosen to ensure high availability. Here, the most important point for cost reduction is the performance of the solvent. In this project, EEWs focus will be on the choice, handling and continual improvement of the solvent to achieve cost reductions. With these measures, EEW intends to achieve significant cost reductions during the course of this project. Other cost reductions are related to learnings in project management and procedures, replication of the technological concept, optimization of the technical design and operations (e.g. more flexible process control and instrumentation).

Another option – for the scale-up phase – is the utilization of other carbon capture technologies with improved energy efficiency. Currently, all these technologies have a significantly lower TRL and high investment costs, but could be advanced by 2025 to the effect that they can be employed on large-scale at lower cost. Knowledge about amine performance that could be gained in the first project phase will be applied in the scale-up phase.

For large-scale CCU deployment, huge amounts of CO_2 will be required. On the long-term when DAC becomes economically competitive a huge CO_2 resource potential becomes available and the capturing would not be limited anymore to the locations where the emitters are located.

Regarding CO_2 resources available from W2E plants, including EEW's plants, there were 492 W2E plants with a capacity of 96 Mtpa of waste in operation in Europe in 2018. Currently, still a large share of the waste in Europe is landfilled. An analysis carried out by European waste incineration association CEWEP in 2019 shows that even if all countries would meet a recycling target of 65% for household waste, a 68% recycling quota for commercial and industrial waste and only 7% of the waste is landfilled, there is a waste incineration capacity of 142 Mtpa required. For this reason, no waste constraints for W2E plants are expected. In a recently published study, the EU Commission confirms that waste will be one major contributor of recycled CO_2 in 2050 (SWD).

3.4.2.9 Economy wide-impact

As stated by the *New Industrial Strategy for Europe*, renewable Hydrogen and CCU applications have economy-wide the potential to transform many (hard-to-abate) industries and transport/maritime applications to reach carbon neutrality. Hydrogen also has the ability to store renewable energy for long periods and in large quantities (e.g. underground storage or in the form of e-molecules), making it an enabler for significant expansion of the renewables capacities in the EU, and demonstrating the importance of the HyNL project to kickstart H_2 networks and underground storage. For example, HyNL will enable the establishment of a H_2 and CO_2 network, the scale-up to multi-GW electrolysis capacity with the ENGIE H_2 roadmap, with the integrated of large-scale underground storage and the integrated value chains between different industrial actors (ENGIE, EEW, OCI but also Gasunie and Groningen Seaport) and flows (H_2, CO_2, e-methanol).

- **Replication of the project across the economy**

If successful, the HyNL & ENGIE H_2 roadmap will be unique in terms of upscaling and replicability to other H_2 offtakers and CCU applications in the region, and other sites in Europe and globally. Indeed, capturing CO_2 from a W2E plant and synthetizing with renewable H_2 into e-methanol is just one of the potential use-cases for renewable H_2 and CCU. The technologies can be replicated to many other use sectors across the economy.

- **Renewable H2 potential in The Netherlands and EU**

The potential H_2 demand in The Netherlands has been studied by ENGIE, based on today's energy demand in different sectors and sector growth projections. Besides industry, there is a large addressable H_2 demand in mobility (e.g. urban buses, trucks, trains) and demand in the form of H_2 derived fuels (such as methanol) for bulk carriers. The study has indicated that the potential H_2 demand in The Netherlands far exceeds the amount of renewable H_2 that can be produced from the ENGIE Hydrogen roadmap, in both (i) a scenario relying on H_2 development in all sectors where it is the most optimal decarbonization option (H_2 rich scenario), and (ii) a scenario mainly relying on electricity as a final energy vector to decarbonize the whole energy system by 2050 (electricity rich scenario).
In the H_2 rich scenario, the ENGIE study has indicated that a total electrolysis capacity of 48 GWe in The Netherlands (of which ~15 Gwe in the Northern region) would be required by 2050 (~5.4 GWe by 2030), to (1) cover all potential H_2 demand (industry, heavy mobility and maritime) and (2) to support the full decarbonization of the region by 2050 in the most cost-effective way. The latter meaning that by 2050 using renewable H_2 in several industries would have a lower total cost compared to alternative low-carbon technologies (blue H_2 or process electrification). Even in the electricity rich scenario (i.e. decarbonization mainly relying on electrification), still nearly 10 GWe of electrolysis capacity would be required in The Netherlands by 2050.
The resulting electrolyzer capacities by 2030-2050 are aligned with different public studies: the *RVO MOOI 2020 Project HyScaling* states that 5 GWe electrolysis capacity is required by 2030, and the future energy scenario in a study for '*Klimaat Akkoord'* resulted in an electrolyzer capacity up to 45 GWe by 2050. Considering that the ENGIE H_2 roadmap represents less than 2 GW by early 2030s, and will be replicable in terms of interaction with key actors in the region and design of the H2 plant, HyNL fits perfectly in the Netherlands renewable Hydrogen potential.

- **Carbon capture potential in Europe**

According to recent data published by the European Commission, by 2050 there will be a significant amount of CO_2 being captured from unavoidable sources, as to achieve the overall carbon neutrality of the European economy. It is estimated that by 2050 a total of around 200-

400 Mtpa of CO_2 will be captured (excl. DAC), including around 100-200 Mtpa of biogenic origin (of which waste will be a major source), and the remainder from industrial processes and fossil origin. In addition, around 150 Mtpa of CO_2 will be captured from the atmosphere through direct air capture technologies. Hence, by 2050 it is estimated that a total of around 350-550 Mtpa of CO_2 will be captured, of which around 200 Mtpa is expected as a feedstock for the production of synthetic molecules and fuels, the remainder is for underground containment. *To put this Carbon capture potential in perspective with the expected e-methanol production by 2050 in Europe (~4 Mt/year e-methanol in the EU, i.e. ~ 6 Mt/year of* CO_2 *required), the European carbon capture potential would be high enough to produce the necessary volumes of future e-methanol demand (and other applications for* CO_2*).*

- **Global GHG impact at the level of the sector**

For the e-methanol consumption in the global maritime sector, IRENA estimates a global market demand of 40 Mtpa of e-methanol is estimated by 2050 to substitute fossil fuels, such as heavy fuel oil in the maritime sector. Replication of the HyNL project globally for this market could avoid 52 Mtpa CO_2e.

Additionally, HyNL also produces Hydrogen for mobility uses, this global market for Hydrogen mobility (trucks, buses, ships, trains) is estimated at 93 Mtpa by 2050 (excluding methanol for shipping) and thus represents an additional 633 Mtpa CO_2e that can be avoided. We refer to the GHG calculation Excel file for details on the calculation (sheet 'Scalability' for details on the calculations and sources used).

- **Global GHG impact outside the sector**

The HyNL solution of H_2, CO_2 and e-methanol can be replicated outside of the sector (refineries), namely for the production of methanol for chemical end-uses, which represents a global demand of 100 Mtpa by 2050. Therefore, methanol for chemical use replicating the HyNL solution can save 203 Mtpa CO_2e.

- **Reinforcement of existing value chains, and creation of new ones in Europe**

The project will support the creation of new and the reinforcement of existing value chains in Europe, as defined in the New Industrial Strategy for Europe and the communication on a recovery plan for Europe.

Thanks to the development of e-methanol production at BioMCN, the project is ensuring the local methanol production in The Netherlands on the long run and kickstarting a new value chain of synthetic fuels in Europe which is today non-existent. Thanks to the local methanol production and related scale-up, Europe will reinforce their industrial and strategic autonomy, allowing to develop its own markets, and be less dependent from imports from non-EU countries, contributing as well to other projects such as a local Hydrogen import value chain between Portugal and The Netherlands.

The project will also contribute to the integration across value chains and sector coupling (i.e. smart sector integration), namely the electricity sector (sourcing additional wind offshore electricity from Holland Kust West, located in NL), the gas sector through production of renewable H_2 and injection into the Gasunie H_2 backbone (conversion of old natural gas pipelines into H_2 pipelines, and new H_2 pipelines), and the offtakers, where OCI will be able to reduce its natural gas consumption and dependence (e-methanol production instead of fossil-based methanol), and selling renewable H_2 to other offtakers (reducing their dependency on fossil fuels), such as the transport sector (buses, trains), steel industry, datacenters and others. Finally, the project will create a new value chain by linking to the liquid fuels sector, as the produced e-methanol will most likely be consumed in the maritime transport sector which today is heavily dependent on fossil fuel import. Therefore, e-methanol will allow to decarbonize the maritime sector.
The project will support also the 'energy efficiency first' principle to reduce emissions across industry at the lowest total cost. The project will support a more strategic approach in the efficient integration of renewable off-shore wind electricity, which will avoid grid congestion and renewable curtailment. Finally, a state of the art efficiency of the electrolyzer will be a key selection criteria for the choice of electrolyzer technology and supplier.
The consortium will also look closely at opportunities with local industrial ecosystems, such as collaborations with local universities (see section on Project scalability), preferring European manufacturers of equipment (e.g., Siemens, Technip, Cummins, ITM…) and the close interaction with Hynetwork and Groningen Seaport for the H_2 backbone and CO_2 pipeline development.
To conclude, the project could be an important catalyst in creating new circular economy activities. As Groningen Seaports considers to construct open access networks for various utilities. With the realization of a CO_2 delivery pipe between EEW and BioMCN, the project will be the first 'customer' of such a CO_2 network needed to further scale up a wider CO_2 network to which other CO_2 producers and consumers could connect to and trade the product. Similarly, the project will develop a renewable H_2 auctioning to ensure faster supply/demand convergence between renewable H_2 producers and consumers.

3.4.3 Innovation

The HyNL consortium considers a 100 MW H_2 plant as the optimal scale, as it provides a good trade-off between technical, financial and commercial considerations. First, the 100 MW electrolyser scales up the current state-of-the-art by a factor 5, which makes sense in view of current engineering designs for large-scale Hydrogen plants and corresponding manufacturing availability from the supply market pointing towards 100 MW. Moreover, a break-even can be achieved when 75% of the H_2 plant's production is used for e-methanol production considering a remaining load factor of 25% serving the mobility or other markets. This also leaves room to explore other market segments through Hydrogen auctioning to accelerate the development of the Hydrogen economy. Additionally, BioMCN currently operates 2 lines each producing 350 ktpa of methanol. Producing 56 ktpa of e-methanol within HyNL (and further scale-up beyond the project horizon) allows a gradual conversion of the BioMCN facility towards higher renewables-based share while managing the risk of the investment, jointly with the biogenic CO_2 sourcing ramp-up. Finally, a minimum Hydrogen volume has to be secured to justify the investment in the Hydrogen infrastructure (backbone and storage in salt caverns) by Gasunie, which is a true enabler of the Hydrogen economy in the Netherlands.

- **Innovation beyond state-of-the-art**

In this section, we describe how HyNL goes beyond incremental innovation, covering the following: plant design, operating approach, performance and quality, economics and commercial aspects, construction, reliability, availability and maintenance. Relevant Technical, Commercial and System Readiness Levels (TRL, CRL, SRL) are provided and we labelled the innovations as breakthrough, very strong, strong or intermediate in the lists of 'Key Innovations'. A summarizing overview of the TRL levels of all HyNL technology elements is provided below.

- **Plant design:** *key Innovations*
  - ✓ A first of a kind large e-methanol production plant of unprecedented scale
  - ✓ …and nature, including 3 distinct yet interconnected plants and connection to a Hydrogen transport and storage facility
  - ✓ A 100 MW flexible electrolyzer plant, able to follow the rapid fluctuations of renewable energy sources
  - ✓ A carbon capture plant harnessing biogenic CO_2 from a waste-to-energy plant for e-methanol process use
  - ✓ Digitized energy management and certification systems optimizing the entire value chain

  HyNetherlands is based on the production of renewable (RED2 compliant) Hydrogen and its reaction with CO_2 in a chemo-catalytic process to produce renewable methanol. The current reference technology is therefore the CRI project in Iceland, and HyNetherlands represents an upscaling of a factor of 14 in terms of e-methanol production capacity.

	CRI Pilot Plant	HyNetherlands
Electrolyser	6 Mwe	100 Mwe
CO_2 recycled	6,000 tpa	77,500 tpa
Renewable methanol production	4,000 tpa	56,000 tpa
Technology readiness level	TRL 7	TRL 8-9
Power supply	Constant renewable energy	Fluctuating renewable energy

Table 3: Scale of the HyNL project as compared to the state-of-the-art.

The HyNetherlands 100 MWe electrolyzer plant also represents a strong innovation as compared to current comparable installation (20MWe). A 100 MW electrolyzer is recognised as an important strategic innovation milestone of the European Union industrial and climate strategies[5]. The electrolyzer plant design of HyNL will also be designed for integration with intermittent renewables such as solar and wind, which is extremely challenging. The vast majority of the renewable electricity used to produce the renewable Hydrogen will be offshore-wind-based and can rapidly and frequently fluctuate. Therefore, HyNL will select an electrolysis technology able to follow rapid fluctuations (technically possible for the 5 shortlisted pressurized alkaline and PEM designs). Note that HyNL has willingly not selected one single electrolyzer technology to date, in the interest of cost efficiency, since the electrolyzer market is in constant evolution in terms of offering and performance. To reconcile intermittent renewable power and non-flexible e-methanol production process, HyNL will also unlock large scale Hydrogen storage. The latter is planned within HyNetherlands as a combination of local storage at Eemshaven, storage within the Hynetwork (re-purposed) pipeline linking Eemshaven and Delfzijl (line packing) and, once available, storage of Hydrogen in the form of salt caverns. These aspects will demonstrate a strong systemic innovation and third party integration of the HyNetherlands value chain as the CRI pilot-plant is developed to have access to constant renewable energy. In that view, the SRL will be scaled up from 2 to 4.

A further particularity of the HyNetherlands value chain is the production of e-methanol from biogenic CO_2 captured on a waste incinerator, which is innovative with respect to state of the art and circularity. HyNL will also overcome the main obstacles for industrial-scale utilisation of carbon capture technologies, with particular focus on performance degradation of amines and high thermal energy demand, and will as such contribute to advance maturity of carbon capture technologies on waste-to-energy plants that are only at demonstration stage up to now.

- **<u>Operating approach:</u>** *key Innovations*
  - ✓ A digital innovation will be achieved through demonstration (TRL 8) of a bankable performance software model and AI-enhanced Energy Management System
  - ✓ A tracking system will be deployed covering the full electricity to e-methanol value chain.

HyNL will develop and use a bankable performance model to increase robustness of the plant integrated design and further mitigate performance risk, supporting bankability demonstration towards future lenders. Commercially available products have been identified but these are all lacking the ability to represent a large scale plant in detail for bankability purpose and interface with an external EMS for its testing. Also, no holistic EMS currently exists that serves the needs of HyNL. Therefore, HyNL will rely on in-house developed digital tools that solve the key challenges associated with the state-of-the-art. A detailed performance model mimicking the behaviour of the integrated value chain, with EMS interfacing ability, has already been developed to demonstrate the bankability of the proposed system design and is being used to define the best operating strategies and derisk the system design (under degraded modes and intermittent conditions). This model will evolve into a digital twin by integrating the detailed design and the performance test data. This strongly innovative combination of digital tools will advance the current state-of-the-art (TRL 6) by optimizing the plant operation accounting for the multiple ramifications of the value chain. An innovative fully-functional EMS holistic approach will be demonstrated (TRL 8) by synergising and optimising the following vectors: (i) day-ahead and longer term offshore wind production (uncertain) forecasts and realized data (ii) control of the fast-cycling electrolyzer considering its live H_2 delivery capacity (iii) forecasted market prices and interactions with the day-ahead, intraday and imbalance power markets (iv) management of the state-of-charge of the large-scale H_2 storages (first line packing and later salt cavern) as well as local H_2 storage (v) e-methanol plant H_2 offtake and forecasted demand (vi) other Hydrogen offtakers and their forecasted demand. The EMS will dispatch the HyNL value chain down to the Hydrogen offtake to maximize the production of renewable Hydrogen and minimize its cost, within the applicable technical and contractual limits of the complete system.

Besides, HyNL will deploy a tracking system spanning the complete electricity to e-fuel value chain. While different forms of tracking are currently in place, the deployment of an integrated tracking across the complex (multi-vectors and multi-sites) value chain of HyNetherlands (spanning electricity, Hydrogen, CO_2 and e-methanol) is seen as a further systemic innovation exceeding state of the art (SRL goes from 2-3 to 4). Such an innovation will be implemented while closely following the – still evolving – RFNBO certification rules and facilitated by the fact that mature tracking solutions do exist at sub-system level (electrical meters, H_2 and CO_2 flow meters, mass balance methodologies already in place for bio-methanol).

- **Performance and quality:** *key Innovations*
  - ✓ The pressurised Hydrogen plant will be built with particular focus on circularity and energy efficiency, including a targeted electrolyzer specific consumption of 51.9 kWh/kg (to be confirmed after contractor and OEM selection in Q3 2022) at nominal load (BoL), and energy efficiency savings of 60 GWh/y
  - ✓ HyNL will ensure that mostly RED2 compliant H_2 and biogenic CO_2 are delivered to BioMCN
  - ✓ The renewable power supply of the HyNetherlands electrolyzer consists of a fixed price offshore wind PPA and an Energy Management Service Agreement
  - ✓ Performance of the entire value chain will be monitored and optimized by an innovative set of digital tools.

The HyNL electrolyzer will feature increased integrated flexibility (a minimum ramp rate of 3%/s is required, in line with the system solicitations to be expected when running on offshore wind energy, and confirmed compatible with multiple pressurized alkaline and PEM designs. The overall Hydrogen plant design and oxygen valorisation will trigger energy savings in excess of 60 GWh/y compared to the state-of-the-art.

E-methanol produced in HyNL will need to be certified as e-fuel (liquid or gaseous fuel made from electricity), complying with the RED2 directive, to enable substituting grey methanol . Therefore, a long term as-produced fixed price Power Purchase Agreement ("PPA") will be contracted consisting of a capacity of 200 MW of a new non-subsidised offshore wind farm providing sufficient energy to meet HyNL's demand for RED2-compliant Hydrogen. Additionally, an Energy Management Service Agreement ("EMSA") will provide the Energy Management System ("EMS") of HyNL with the necessary visibility (renewable power, market prices and once available, CO_2 intensity forecasts) and access to the power markets.
The combination of the HyNL PPA, EMSA and EMS is a truly innovative approach that will allow the HyNL EMS to steer the electrolyzer to follow as closely as possible (with a future proof design on a 15 min basis) the sum of the energy production under the offshore wind PPA (for RED2 compliant Hydrogen) and the electric energy purchased in the spot market (for renewable Hydrogen).
The ENGIE H_2 plant and OCI e-methanol plant will be connected through the Hynetwork H_2 transport and storage system. The Hydrogen grid specification set by Hynetwork only ensures 98% purity and allows a sulphur content that can damage the catalyst in the methanol synthesis reactor. As no desulphurization catalyst exists for a 98% pure Hydrogen stream, the innovative approach is to inject the Hydrogen already in the reformer section and not in the synthesis loop of the methanol production plant; as the renewable Hydrogen stream is mixed with natural gas the existing desulphurization method can be used.
Lastly, HyNL will also establish a certification and product labelling mechanism to qualify the CO_2 stemming from the biogenic share of the waste as "green".

- **Economics and commercial aspects:** *key Innovations*
  - ✓ HyNL will trigger a market for e-methanol as innovative substitution fuel and feedstock
  - ✓ A Hydrogen auctioning will be created to sell the surplus Hydrogen produced at the ENGIE H_2 plant
  - ✓ HyNetherlands will be an enabler for the creation of a Hydrogen hub and ecosystem in The Netherlands

Inspired by the bio-methanol sales and marketing strategy of OCI, HyNL will develop the e-methanol business by a.o. prospection with major shipping companies and ship engine Original Equipment Manufacturers ("OEMs") and triggering demand-pull in the chemical sector. The HyNetherlands project also features significant competitive advantages on which it will capitalize to overcome the barriers to commercialization of e-methanol:

- ✓ Strong partners, together in control of industrial sites and facilities that allow production of e-methanol, including future scale up to trigger cost reductions.
- ✓ A systemic value chain in favour of e-methanol robustness of supply with (i) large Hydrogen storage in the form of linepack and salt caverns, (ii) a biogenic CO_2 capture with a second line able to act as back-up, (iii) an existing methanol production site and

logistical chain, offering the option to rely on product storage and temporary use of bio-methanol as alternative if ever required.

- ✓ A Hydrogen and CO_2 cost structure making the supply of e-methanol under fixed prices more accessible. This will be enabled by the long-term fixed price renewable energy PPA and the waste-to-energy process producing the biogenic CO_2 being stable with long term availability of supply.
- ✓ HyNetherlands leverages on the existing methanol logistics of OCI as a leading player to ensure presence of the e-methanol at the key maritime ports where it will be needed.

Alongside the production of e-methanol, the HyNetherlands project also foresees sales of near 3 ktpa of renewable Hydrogen to other offtakers than OCI along the Hynetwork backbone and the local mobility market. With the ultimate objective to trigger a to-become-conventional market, a Hydrogen auctioning process will be organized towards these offtakers, which is seen as a commercial innovation in the project. Auctioning is certainly a mature commercial process (CRL 9), but its application to a new product, namely renewable Hydrogen alongside specific conditions is innovative.

Finally, HyNL kick-starts the very first deployment of infrastructure for transport and storage of renewable power through Hydrogen. Being a launching customer and achieving filling and pressurisation of the Gasunie Hydrogen pipeline (Hynetwork Services) and possibly filling of Gasunie salt caverns with cushion gas (HyStock), HyNL is a true enabler for the European Hydrogen ecosystem that is rapidly developing. HyNetherlands will also be one of the first projects storing its produced Hydrogen in large-scale underground storage (HyStock), also located in the North of the Netherlands.

- **Construction:** *key Innovations*
  - ✓ HyNL is anchored in existing facilities by retrofitting a power plant, waste incineration plant and methanol production plant, thus making optimal use of existing infrastructure
  - ✓ HyNL will connect to a Hydrogen backbone (retrofitted disused natural gas pipeline) and CO_2 pipeline, materializing an integrated value chain out of the three distinct existing facilities

- **Reliability, availability and maintenance:** *key Innovations*
  - ✓ A digital twin solution will monitor the performance of the H2 plant, help optimize operation and availability by early anomaly detection and support operators training
  - ✓ Buffering solutions for H_2 are foreseen to ensure availability for e-methanol production

- ✓ At EEW and BioMCN, production lines are redundant due to the anchoring of the HyNL project in existing facilities. This ensures a reliable supply and offtake in case of failure or maintenance.

3.4.4 Contractual principles ENGIE SPV /ENGIE Energie Nederland N.V.

3.4.4.1 Power Purchase Agreement and Energy Management Services

In order to produce qualifying Hydrogen, the ENGIE H_2 plant is expected to source the majority of its electricity needs (approx. 70%) from an offshore wind farm pursuant to a Letter of Intent. The remaining part of the ENGIE SPV electricity needs (approx. 30 %) will be covered by grid electricity and corresponding guarantees of origin (coming from the 200MW wind offshore PPA surplus of production).

As the electricity supply has to respect certain parameters, it is further envisaged that an energy management service agreement will be entered into by the ENGIE SPV with another ENGIE affiliate specialized in energy management. For efficiency reasons, the electricity supply and energy management service agreement will be combined and the ENGIE affiliate responsible for the energy management will be the sole interface for the ENGIE H_2 plant.

3.4.4.2 EPC Contract

To reduce interfaces and related risks, the ENGIE SPV will enter into a single engineering, procurement and construction contract with a contractor (consortium) containing guarantees for the ENGIE SPV in terms of project timeline, quality, performance and budget.

A number of key selection criteria will allow ENGIE to nominate by October 2022 one or maximum three bidders to prepare a basic design allowing them to provide a final and binding offer, in Q1-2 2023. Tractebel Engineering will provide technical support throughout the selection process, the following criteria will play a key role in the final selection:

- Safety management plan, standards and track record
- Compliance to ENGIE's key technical (i.e. plant operational flexibility, construction timeline and scope) requirements, terms and conditions criteria
- Project Management approach, quality and risk management
- Efficiency and degradation guarantees
- CAPEX and Long-Term Maintenance Agreement Price, Total Cost of Ownership
- Sustainability and innovative approach (incl. regarding EOL recycling & efficiency of materials reuse)
- Potential for improvement of the offer before final contract signature
  Effectiveness of the contract is anticipated to start not later than at project FID.

3.4.4.3 Shared Facilities Agreement and Land Lease Agreement

Considering the electrolyzer will be constructed on the existing ENGIE Eems site, a

(i) land lease agreement and

(ii) (ii) shared facilities agreement will have to be formalized prior to FID between the HyNL SPV and ENGIE Energie Nederland NV for respectively the lease of the plot and the supply of certain services and products already available on the ENGIE Eems site. The agreement will formalize the quantities and types of services to be provided including their limits.

Scope	**Description**
Site security	The existing site security services to be extended to cover the electrolyzer plant and auxiliaries
O&M services	Quality, environmental, health & safety scope, operations and maintenance will be performed under the existing plant management structure. The teams will be responsible for the daily operations and maintenance activities, prepare the related procedures and workplans prior to the commercial operation, plan and supervise outage activities as well as the activities performed under the OEMs Long Term Service Agreements
Demin water supply	A capacity of maximum 20 m^3 per hour demineralized water.
Grid Connection	The project is connecting behind the ENGIE Eems power plant Grid connection with TenneT, hence the agreement with TenneT to increase the import power from 12MVA currently to 125MVA in the future will need to be coordinated under the ENGIE Eems power plant EC7 Unit grid connection agreement. Further this scope includes the alignment of the outage maintenance of the common connection to the grid in order to reduce as much as possible the associated downtime and plan synchronously the electrolyzer plant maintenance.
Seawater supply	10% of the cooling water flow provided to one if the Eems units will be made available via existing supply and discharge connection points. 10% of the cooling water flow provided to one if the ENGIE Eems units will be made available via existing supply and discharge connection points. Redundant supply lines are foreseen in the design.
Fire water supply	The existing plant fire water supply system has been proven sized sufficiently to also fulfil cooling needs of the electrolyzer plant, the EPC Contractor can tie-in to an existing connection point in the ENGIE power plant.

Compressed air supply	If needed compressed air will be supplied from the Eems plant. If needed compressed air will be supplied from the ENGIE Eems power plant. This will be confirmed by Q3 2022 when the EPC Contractor basic design is available.
SG&A	Stakeholder management support, Communications, IT, HR, Finance and accounting support will be provided via the ENGIE Energie Nederland headquarters organisation

Table 4: Contractual topics with the Eems Power Plant

3.4.4.4 Oxygen Offtake Agreement

In parallel to the HyNL Project, ENGIE is also developing a 40MW thermal capacity gasification project at the ENGIE Eems site, that will generate approximately 40 million Nm^3 of syngas out of woody waste ("Chameleon Project"). This Chameleon Project should be ready for FID by end 2022 and if achieved, COD by end 2024 or early 2025.

As the Chameleon Project has a need for oxygen, it is foreseen that a volume of 9.2ton O_2/h during a period of 15 years will be contracted by the Chameleon Project from the Hydrogen SPV, with build in flexibility to manage the intermittent nature of power supply. The oxygen will be delivered 'as is' (meaning: no purification, pressurization or storage capacities are foreseen in the scope of the HyNL project).

ENGIE has identified other potential offtakers and is in the process of securing alternatives to the Chameleon project for the oxygen offtake. A steel manufacturing company is planning to install itself nearby the electrolyzer project site, Groningen Seaports has already indicated that there may be an interest of this company which will be further explored.

In addition, HyNetworks services (operating the Hydrogen backbone) will use oxygen for embrittlement reduction purposes.

3.4.4.5 Heat Offtake Agreement

ENGIE is planning a study with Groningen Seaport to valorize the waste heat in the provincial heating network project. The objective is to supply the heat network with the waste heat of the electrolyser of HyNL by 2030. However, as the maturity has not yet reached high levels, this is excluded from today's business plan

3.4.4.6 Hydrogen Supply Agreement

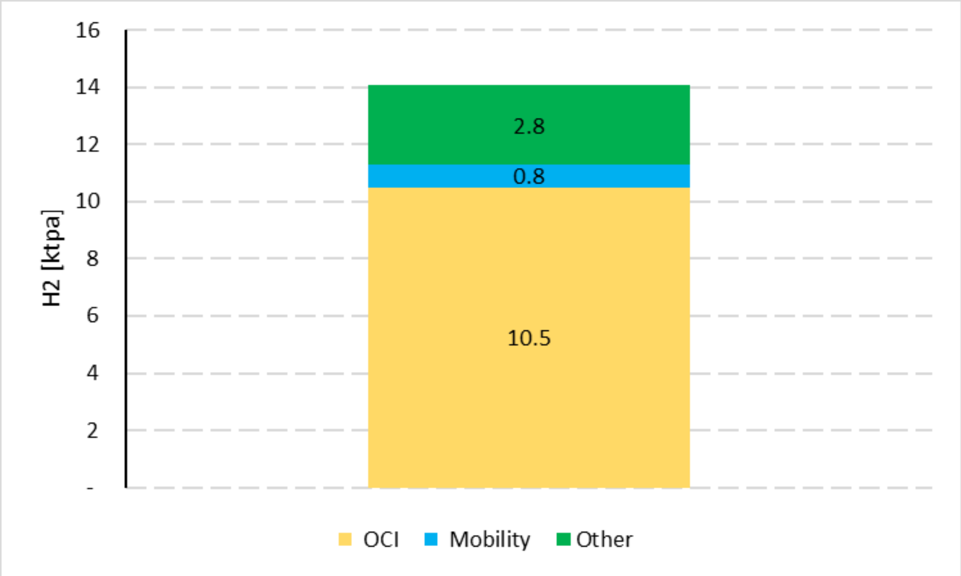


Figure 43: 3 types of Hydrogen purchase agreements (H_2 offtakers)

Three types of Hydrogen Purchase Agreement will be secured:

- With OCI/BioMCN: The majority of the Hydrogen produced by the ENGIE H_2 plant will be RED2 compliant Hydrogen (90%), and supplied to OCI or its subsidiary BioMCN pursuant to a long term, fixed price supply agreement.
- With mobility offtakers: a 5% share of the produced Hydrogen will supply mobility offtakes (offtakers like QBuzz and Provincie Groningen for passenger train for example) This is also anticipated to be RED2-compliant Hydrogen.
- With other offtakers: the remaining Hydrogen will be contracted through an auctioning mechanism towards interested parties.

3.4.4.7 Connection Agreement and Transport Agreement ("TSA")

The tie-in to the Hynetwork backbone will be governed by the Grid Connection and Transport Agreement to be signed between the ENGIE SPV as "Shipper" and the Hynetwork company, as subsidiary of Gasunie. No connection to the Tennet electricity grid is required given the plant is to be developed on the ENGIE Eems plant which already benefits from the Tennet connection.

As the Hydrogen regulatory framework is still under development, these standards and protocols have not yet been finalized by Hynetwork, but several exchanges and workshops between the parties have resulted in a first concept that could be translated in the electrolyzer EPC MFS. Conversations are currently ongoing about the role the HyNetherlands project will play in the start-up of the backbone Phase I operations. HyNetherlands can help to commission and start up the network and eventually during the initial operating period support in maintaining the network stable, this until the HyStock storage capacity will become available.

The pipeline routing from the backbone to the Electrolyzer site will be built by Hynetwork, to avoid this ‘private’ part to be built again in future phases, the capacity of this pipe considers the Hydrogen volumes foreseen in the ENGIE Hydrogen roadmap.
This agreement will also stipulate the requirements in terms of signal exchange between the parties required to operate the backbone smoothly. The Hydrogen metering station that will be owned and operated by the ENGIE SPV and build as per Hynetwork required standards and protocols.

3.4.4.8 Hydrogen Storage Agreement

The HyNetherlands Project will contribute to triggering the deployment of Hydrogen underground storage through salt caverns. This will bring extra flexibility to HyNL due to the enhanced Hydrogen storage offered by the salt caverns, developed by HyStock B.V. (“HyStock”) a Gasunie affiliate.
Discussions have already taken place with HyStock on the volumes that could be stored and the applicable conditions so that this can be integrated in the electrolyzer EPC MFS.
As the Hydrogen regulatory framework is still under development, certain standards and protocols have not yet been finalized by HyStock. The current understanding between ENGIE and HyStock is reflected through a Letter of Intent.

4 Conclusions

Partners

ENGIE enabled a partnership in the Eemshaven/Delfzijl cluster to enable the production of renewable RED II compliant Hydrogen by partially making use of existing facilities at the ENGIE site in Eemshaven. The renewable Hydrogen will be used to produce renewable e-methanol by BioMCN in Delfzijl, using biogenic CO_2 from the carbon capture of EEW's waste incinerating plant also in Delfzijl. The Hydrogen is transported from ENGIE in Eemshaven to BioMCN Delfzijl by the (to be) converted network of HyNetwork Services and the biogenic CO_2 is brought from EEW to BioMCN by a new pipeline established by Groningen SeaPorts. The required electrical power is sourced from renewable RED2-compliant sources. About 25% of the produced renewable Hydrogen will be made available to the mobility or other markets.

Design and location

The ENGIE site in Eemshaven provides a plot to erect the Hydrogen production plant with the benefits of elements supplied by the existing Eems Power Plant as there are the connection to the national grid, the demin water for the electrolysis, the sea cooling water facility and the integration of the operations in the existing central control room. The value chain is balanced by an Energy Management System developed by ENGIE. The Hydrogen plant location offers the opportunity for further upscaling of Hydrogen production to GW scale.

In close cooperation with HyNetwork Services as future TSO of the Hydrogen backbone in The Netherlands, the tie-in of the Hydrogen production line to the backbone will be established at the boundaries of the site of ENGIE. The metering of the produced product is part of the ENGIE scope and applies to the rules and regulations of the TSO. Until the availability of the salt caverns of HyStock in 2027 ENGIE has the opportunity to balance the flow of Hydrogen to the offtaker by using variable compression levels enabling line-packing in the backbone.

Procurement electrolyzer

Approaching the supplier market by means of a Minimum Functional Specification is a success. This concept covers the traditional FEED-proces without prescribing the electrolysis technology, thus enabling the potential EPC contractors to provide the best technological offer in a possible partnership with an electrolyser OEM based on already available experience from previous project and integrated with new solutions that might not have reached the market yet. The basic engineering shifts towards the selected preferred supplier and is executed before taking the final investment decision by ENGIE.

GHG avoidance

The implementation of the HyNetherlands project will lead to a substantial reduction of GHG-emissions in the value chain of the production of (e-)methanol. First the transition from Hydrogen produced by steam methane reforming (SMR) towards renewable Hydrogen from electrolysis based on renewable sources avoids the production of CO_2 as a by-product and reduces substantially the use of natural gas a feedstock. Secondly by using the biogenic CO_2 for the production of e-methanol, captured at the incineration plant, the emission of CO_2 is significantly avoided by 1,381,760 tCO_2e.

Finance

Producing Hydrogen (LCOH) by electrolysis is substantially more costly than production by the 'conventional way' through SMR. To create a viable project and support the carbon neutrality roadmap roll-out, incentives to activate this market are necessary. Important aspects at this timeframe are the availability of external financial support to close the funding gap but also a stable and reasonable regulatory framework should be in place soon.