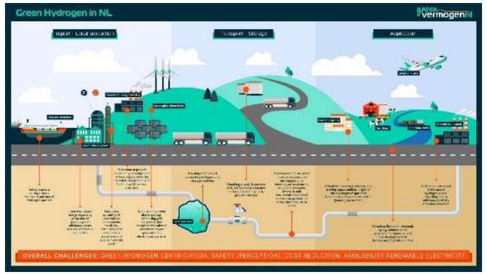
R&D Program



One of the main goals of GroenvermogenNL is to create a strong national innovation ecosystem around hydrogen production and utilization. This calls for an innovation program across the whole TRL-scale, stimulating short-term applied research (see also pillars Pilots and Demos) as well as long-term fundamental research (the R&D pillar).

The R&D pillar aims to bring together all relevant national expertise on hydrogen and green electrons as basis for complex chemistry. A coordinated effort on R&D is essential not only for upscale and acceleration of hydrogen production and utilization, but also to further strengthen the collaboration between companies and knowledge institutions and stimulate new partnerships, while avoiding replication and blind spots at the national level. To this end, the R&D program focuses on seven work packages spanning a broad innovation spectrum (TRL 2-6) from industrial to applied and fundamental research. Interaction and knowledge dissemination between the work packages is strongly encouraged, and is also a key aspect of WP7.

The R&D program will contribute to resolve technical uncertainties, accelerate the intended cost reduction and develop innovative business models for climate-neutral hydrogen in the future energy system.

The seven Work Packages of the R&D pillar of GroenvermogenNL are:

1. Making carbon-neutral H_2
2. Transport and storage of H_2
3. Direct use of H_2
4. H_2 & green e^- for C-based chemistry
5. H_2 & green e^- for N-based chemistry
6. Green H_2 & e^- for specialties
7. Socio-economic aspects & implementation of H_2

WP1: Making carbon-neutral H_2

Cost-efficient large-scale production of carbon-neutral hydrogen is a key element in the transition to a climate-neutral economy. Given the rapid rise and application of solar and wind energy, water electrolysis is a logical route. An analysis of the first projects, the estimated required capacity and the potential market shows that we are only at the beginning of the development of this new industry. This part of the program is therefore aimed at reducing the (system) costs of water electrolysis to 2.5 €/kg H_2 by 2030, and at rapidly increasing the production of electrolysers. In addition, there are relevant, possibly disruptive, transition technologies that prepare the chemical industry for the use of this green hydrogen. This route simultaneously produces both carbon-neutral hydrogen and a usable carbon-based feedstock (e.g. carbon black or precursors for higher order hydrocarbons).

Scope:

Realization of cost-efficient production of green hydrogen; specific tasks:

- Development of the Dutch supply chain for materials, components and systems for AWE and PEM electrolysers and fuel cell stacks
- Develop, analyze and test the performance of innovations for AWE and PEM electrolysis technologies
- Development of low TRL AEM and SOEC electrolysis technology
- R& D for transition technologies CO_2 neutral hydrogen production from methane

Activities include:

- R&D into critical components of electrolysers incl. cost targets at component level (MEA, Bipolarplate , catalyst, etc
- AWE, PEM, AEM and SOEC electrolysis technologies
    - Development of benchmark tests, system architectures
    - Small scale demonstration of pilot manufacturing line
- Transition technologies CO_2 neutral hydrogen production from methane:
    - R&D
    - Realization of pilot plant Hüls process) in 2022 and demo plant in 2025

WP2: Transport and storage of H_2

So far, transport and storage of hydrogen are limited because almost all hydrogen is taken up directly as an energy carrier and feedstock in industry. With the scaling up of hydrogen production for deployment in the energy system, it is necessary to examine whether and to what extent the existing intensive transmission and distribution network for natural gas that is present in our country and connects us to surrounding countries can be used in a safe and acceptable manner for the transport of hydrogen. The question also arises as to whether the gas grid requires modification or expansion for the purpose of hydrogen transportation, for example due to installation of large-scale electrolysis capacity. Safety is the key requirement here, not only of the transportation system but also of the various applications and storage of hydrogen. Therefore, research is needed into the large-scale storage of hydrogen in, for example, tanks, cylinders or salt caverns and other underground storage capacity.

Scope:

This work package focuses on managing:

- Grid requirements for gas quality and pressure issues for hydrogen transportation,
- Safety issues related to the entire hydrogen value chain and organization Safety issues with them
- Scaling up the introduction of hydrogen from local to national energy systems
- Design issues to an international hydrogen network including the role of the North Sea energy
- Offshore hydrogen production, conversion, transportation and storage
- Multidisciplinary aspects of large-scale hydrogen storage in salt caverns and empty gas fields, onshore and offshore

Activities include:

- Knowledge development in the field of transport and storage infrastructure.
- Development of safety standards incl. setting up national safety center H_2 transport and storage.
- Development roadmap for transition in NW Europe.
- Analysis and optimization offshore hydrogen production, conversion, transport and storage.

WP3: Direct Use of H_2

The current global hydrogen produced from natural gas is currently used primarily as feedstock for industrial processes, for example in oil and biomass refining and ammonia production. However, the direct use of hydrogen can also be attractive in energy-intensive industries for decarbonizing processes requiring high temperatures. In power generation, hydrogen, and in some cases derivatives of hydrogen such as ammonia or methanol, can be used in fuel cells or on a large scale in (modified) natural gas turbines. In addition, hydrogen can be used in the mobility sector in a fuel cell electric drive or as a climate-neutral fuel in internal combustion engines.The built environment is also an interesting sector for the use of hydrogen in heating homes. Here it is important to determine in which segments of the built environment the application of hydrogen is optimal. It is also important to understand the instruments that take into account financial, environmental, safety and comfort aspects as well as the social impact.

Scope:

This work package aims to analyze:

- Use of hydrogen as a fuel and feedstock in (energy-intensive) industry and for power generation
- Use of hydrogen as a fuel in mobility and built environment
- System aspects of hydrogen deployment in different value chains
- Non-technical aspects of hydrogen deployment (policy, instruments, support base)

WP4: H_2 & green e^- for C-based chemistry

Our society relies heavily on carbon-based materials, produced almost entirely from fossil sources such as oil and natural gas. Using renewable hydrogen, produced directly from green electrons or through direct use of green electrons, could make many of our current chemical conversion processes more sustainable, directly reducing the carbon footprint of our petrochemical and chemical plants. The envisioned subprogram outlines three directions to achieve these goals. First, the large-scale introduction of green hydrogen, which can be used directly to replace fossil hydrogen. Second, the direct use of green electrons to heat high-temperature chemical conversion processes. Finally, we propose the direct use of green electrons to perform large-scale electrochemical reactions. This route enables the production of bulk chemicals, such as ethylene, propylene and their oxides, as well as fuels and fuel components, such as methanol and kerosene, directly from CO_2. Moving in this direction represents a gradual but substantial shift toward circular chemical production facilities that will make our current chemical plants greener and more innovative.

Scope:

This WP focuses on:

- Direct use of renewable H_2 to reduce CO_2 emissions from large-scale production facilities. These facilities are used to produce transportation fuels (e.g. gasoline, diesel, and kerosene), bulk chemicals (e.g., alcohols, olefins, and aromatics), and materials (e.g., plastics and coatings, and their precursor molecules)
- Greening the heat processes at these large-scale chemical production facilities through direct deployment of green electrons to heat energy-intensive processes (e.g., endothermic processes)
- Greening of conversion processes in these large-scale chemical production facilities by direct deployment of green electrons for conversion of energy-intensive processes (e.g., electrochemical processes and plasma technology).

Activities include:

Development of:

- Stable and toxin-resistant catalyst materials, more efficient reactor technologies, integrated CO_2 capture and hydrogenation processes for the production of formaldehyde, methanol, DME, ethylene
- New reactor designs and technologies to harness green electrons for heating or lighting large-scale reactors

WP5: H_2 & green e^- for N-based chemistry

Nitrogen is one of the most important elements in living cells and many natural compounds. The synthesis of nitrogen-containing (bioactive) compounds for the production of fertilizers and sustainable plastics is enormously important in modern society. Many of the synthetic routes to nitrogen-containing molecules use ammonia (NH_3) as a feedstock. However, the production and use of ammonia and its derivatives involve high energy consumption and large CO_2 emissions. Grey hydrogen production for ammonia production consumes 1.5% of total global energy demand and contributes up to 7% of the Netherlands' CO_2 emissions. This program line focuses on solutions to this major challenge.

The technology development subprogram of this program line focuses on reducing energy consumption and CO_2 emissions by exploring the feasibility of different integrated production routes to low emission hydrogen and ammonia. The part focused on the fundamental development of new nitrogen chemistry aims to provide innovative plug-in technology and is mainly focused on the use of ammonia as an energy carrier and for sustainable synthesis of nitrogen-containing molecules.

Scope:

This work package focuses on the management of:

- Development of integrated processes for key nitrogen-based platform chemicals (NH_3, ureum) from hydrogen
- Fundamental development of new nitrogen chemistry

Activities include.

Development of:

- gas purification technologies for using biomass for ammonia production, mild Haber Bosch process with in-situ ammonia recovery, high temperature co-electrolysis for the integrated production of ammonia
- NH_3/ureum dehydrogenation catalysts and catalysts for direct ammonia fuel cells with NH_3 as the energy carrier, efficient catalyst with NO_x as alternative oxidant, sustainable alternative methods for the synthesis of N-containing molecules

WP6: Green H_2 & e^- for specialties

The Dutch chemical industry derives a significant part of its turnover from chemical semi-finished products and specialties with diverse applications from automotive parts, packaging, paint and coatings to pharma, food and agro. The production of this huge variety of chemical products is currently still dependent on petrochemicals and multi-step chemical transformations, which generate a lot of waste and consume a lot of energy. The main goal of this program line is to develop new chemical transformations that are cleaner and consume less raw materials and energy through the use of green hydrogen, renewable resources and direct application of green electrons. This will have a major industrial and societal impact and change a significant portion of our current chemical processes. The use of green hydrogen and green (bio-based) feedstocks will enable a "double greening" of the chemical industry. In a second approach, sustainably generated electricity is directly applied (bypassing the initial H_2 formation) to develop clean redox-based chemical transformations and electrochemical-based industrial processes for the production of *specialties*.

Scope:

This WP aims to manage the direct use of renewable H_2 and bio-based feeds for:

- Development of stable and poison-resistant catalyst materials to convert food and agricultural products and their derived intermediates into fully renewable products, in a variety of hydrogenation processes, to replace methane-based H_2
- Demonstration of new process technology by integrating efficient hydrogenation catalysis and (pre)treatment of biomass technologies to convert food and agricultural products into renewable intermediates and monomers for e.g. food ingredients, specialty chemicals and pharmaceuticals.

Activities include:

- Development of more stable and poison-resistant catalysts, more efficient reactor technologies; Production capabilities for renewable chemical platforms
- Demo of integrated catalytic reactor concepts, which are capable to convert renewable H_2 and food, agriculture

WP7: Socio-economic aspects & implementation of H_2

An important question is how the role of hydrogen in the energy system might evolve, given policy, technology, economies of scale, consumer and investment behavior, and how it will relate to other sustainability options and competition and cooperation with other countries. To gain more insight into this, socio-technical system models can be developed to analyze the role of hydrogen in light of the other energy system and economic activities. This includes, for example, cost developments, displacement effects, regulation and market design, and life cycle analysis.

All parts of the hydrogen value chain - production, transportation, storage, conversion and application - can only get off the ground successfully if a number of conditions are met. First, there must be an adequate business case that fits into an appropriate energy sector market design. If not, there must be sufficient other incentives for investors to bet on hydrogen. Second, laws and regulations must provide clear legal frameworks for further market development. Third, there must be sufficient public support so that no objections are raised from society against hydrogen development. It is therefore important to analyze these intersecting aspects in all parts of the value chain in advance and to ensure public support for technological development.

Scope:

Within this WP

- Development of a full transition perspective for the potential and optimal role of hydrogen in the future energy system for different geographical scales (North Sea region, European, international) and markets (industry, built environment, logistics...)
- Analysis and optimization of the business case for introducing hydrogen (grey, blue, green) at different aggregation levels
- Identifications and analysis of the legal and regulatory factors for the introduction of hydrogen: identification of legal obstacles, legal and regulatory framework (national, European, UN) etc.
- Identification of the public acceptance factors for the introduction of hydrogen

Activities include:

- Model development: interlinked multi-scale modeling approach to quantify the role (production, deployment, transport) of hydrogen over time as part of the overall energy system
- Business case development
- Identification & legal regulatory framework
- Identification factors of public acceptance