CALL TO ACTION to foster collaboration between Germany and The Netherlands on green hydrogen & green chemicals

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This publication is an initiative of ECCM (National Advisory Committee on Electrochemical Conversion & Materials). The committee, appointed by the Dutch government, has been coordinating the R&D efforts of companies and knowledge institutes in the Netherlands in the field of short-term hydrogen and systems integration and longer-term electrochemical conversion since 2017. During this period, a portfolio of research programmes and pilot and demo projects (TRL 1 to 7) has been built up.

More information: www.CO2neutraalin2050.nl

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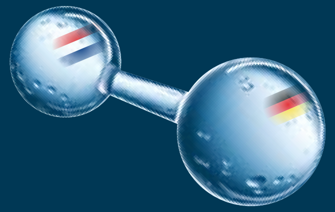
“We have a longstanding tradition between the Netherlands and Germany as far as cooperation in gas is concerned. We would like to build on this and continue cooperation on green hydrogen and green chemistry.”

Winfried Horstmann
Director General for industrial policy from the German Ministry of economic affairs and energy (BMWi)



Focco Vijselaar
Director General for Enterprise and Innovation of the Netherlands ministry for Economic Affairs & Climate Change

“We have each other a lot to offer with respect to first class knowledge, infrastructure and vital industrial clusters to make the transition really happen.”

Preface

The German–Dutch bilateral expert committee presents this call to action for bilateral collaboration in green hydrogen and green chemistry driven by renewable electricity. It is the result of the work of the committee and the input from more than a hundred Dutch and German experts from industry, knowledge institutes, regions and governments, collected in a workshop last October (2020) in Vaals (The Netherlands). They aligned visions and jointly formulated potential areas for collaboration.

The reasons to intensify collaboration on green hydrogen and electrochemical conversion processes between Germany and The Netherlands are as compelling as they are numerous. Both our countries committed to net zero emissions in 2050 and getting there will be an enormous challenge. We need to solve the distribution and storage issues inherent to renewable energy sources like wind and solar. We need to develop technologies and infrastructure to produce fuels and other energy carriers, materials and chemical products from (green) feedstocks using renewable energy. And we cannot delay action.

To make green hydrogen a commercially viable option, the brightest minds from science and industry need to come together now.

Fortunately, bilateral collaboration between The Netherlands and Germany can build on existing strengths and relationships and on past experience. We both not only have a lot to gain but also a lot to offer. Germany has unique infrastructure and national initiatives like the excellence clusters, Kopernikus projects, living labs and energy research networks. The Netherlands has multilateral public–private collaboration across disciplines and sectors in its DNA. Bilateral collaboration will let us draw upon each other’s strengths and combine complementary expertise to together advance our respective ambitions.

We hope this call to action inspires more collaboration in the areas identified and can be a basis for a forthcoming bilateral programme. If, like us, you recognize the urgency and the potential, please join us in action.

The German–Dutch bilateral expert committee

Prof. dr. Matthias Wessling
RWTH Aachen University

Drs. Marco Waas
Dutch ECCM committee,
Nobian

Dr. Thomas Goergen
Covestro

Prof.dr.ir. Richard van de Sanden
Dutch ECCM committee,
TU Eindhoven
EIRES, DIFFER

Executive summary

Climate change is a real, clear and present, and imminent threat. Record concentrations of greenhouse gases (GHG) like CO_2 in the atmosphere result in global warming that will have severe consequences, including more numerous and more extreme weather events, rising seas, increasing risks of wildfires, lost crops and drinking water shortages, and threats to biodiversity, wildlife and their habitats. To achieve the goals agreed in the Paris Climate Agreement – limiting the rise of temperatures to below 2˚C compared to pre-industrial times – the world needs to change the way it produces and uses energy.

This energy transition, however it may eventually play out, will inevitably require a strong shift towards renewable energy to generate (electrical) power and defossilize end-uses. Hydrogen is a crucial enabler of this transition, as an energy carrier and storage medium and for applications that cannot be easily defossilized by electricity – such as heavy transportation and high temperature heat in industry. The transition will also require major advances in electrochemical conversion and materials technology, to convert feedstocks – using sustainable energy – into building blocks for chemicals, materials, energy carriers and fuels. Around the world, initiatives are being announced to produce and use (green) hydrogen, and advance green chemistry, and Germany and The Netherlands are clear frontrunners.

Germany and The Netherlands have both set out hydrogen and green chemicals strategies with very similar visions and very complementary ambitions. Both see high and growing domestic demand for green hydrogen and green chemicals, to be met by new domestic (green) electrolysis capacity and imports. Moreover, Germany wants to become a leading global supplier of hydrogen technology and The Netherlands aims to be the hydrogen hub for North-West Europe. Their respective ambitions are driven by pro-active government departments and the strong capabilities and partnerships between their companies, academic groups and applied research organizations. Bilateral collaboration in green hydrogen and green chemicals can help both countries advance their ecological and economic ambitions.

On October 8th 2020, a virtual workshop brought together over a hundred experts from Dutch and German industry, knowledge institutes and governments to identify and discuss common challenges and potential areas for bilateral collaboration. The results are summarized here and represent a call to action: to reach the goal of net zero emissions in 2050 – given the long lead times and large investments needed for energy infrastructure – this decade is particularly crucial. There really is no time to waste.

With the input from the workshop, the bilateral committee formulated six recommendations.

1. **Intensify R&D collaboration between The Netherlands and Germany**
2. **Develop a (joint/aligned) energy transition roadmap**
3. **Align national programmes**
4. **Bring together complementary expertise in bilateral projects**
5. **Pursue collaboration on key enablers**
6. **Organize innovation missions and connect new supply chains**

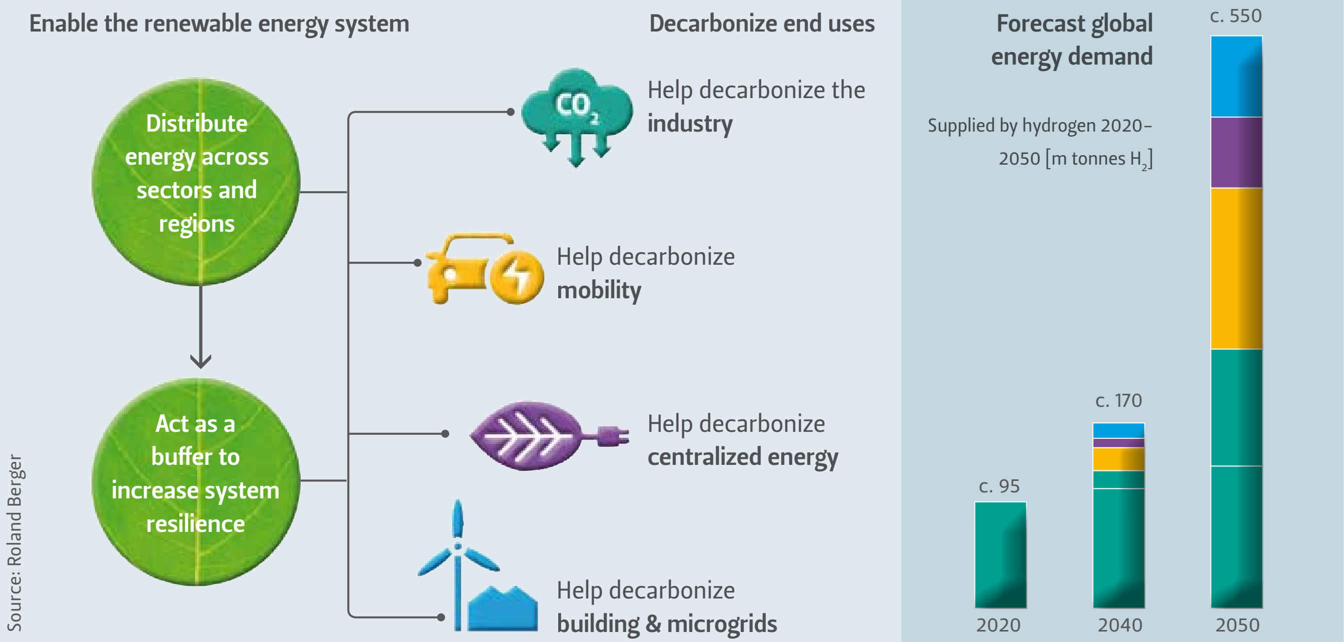
The need for green hydrogen and green chemicals

Today, most of global annual energy demand (~14 bn tonnes of oils equivalent, toe) is used to generate power (38%), followed by transport (19%), industry (15%) and (heating of) buildings (14%). Most is produced by burning fossil fuels (~80%). The share of renewable energy is modest and – contrary to common belief – has not changed much over time (figure 1). Power generation especially relies on fossil fuels and consequently the energy sector accounts for almost two thirds of global GHG-emissions.

Every GHG-emissions reduction scenario developed by the International Energy Agency (IEA) includes a big increase in non-fossil fuelled electricity, with renewables contributing half to three quarters of supply by 2040. Hydrogen is a crucial enabler of this transition (figure 2). First, it is an energy carrier and a storage medium that enables distribution and can act as a buffer for (seasonal) fluctuations in renewable energy supply and demand. Second, (green) hydrogen is a solution for energy application areas that are otherwise difficult to defossilize, such as heavy transportation and high temperature heat in industry.

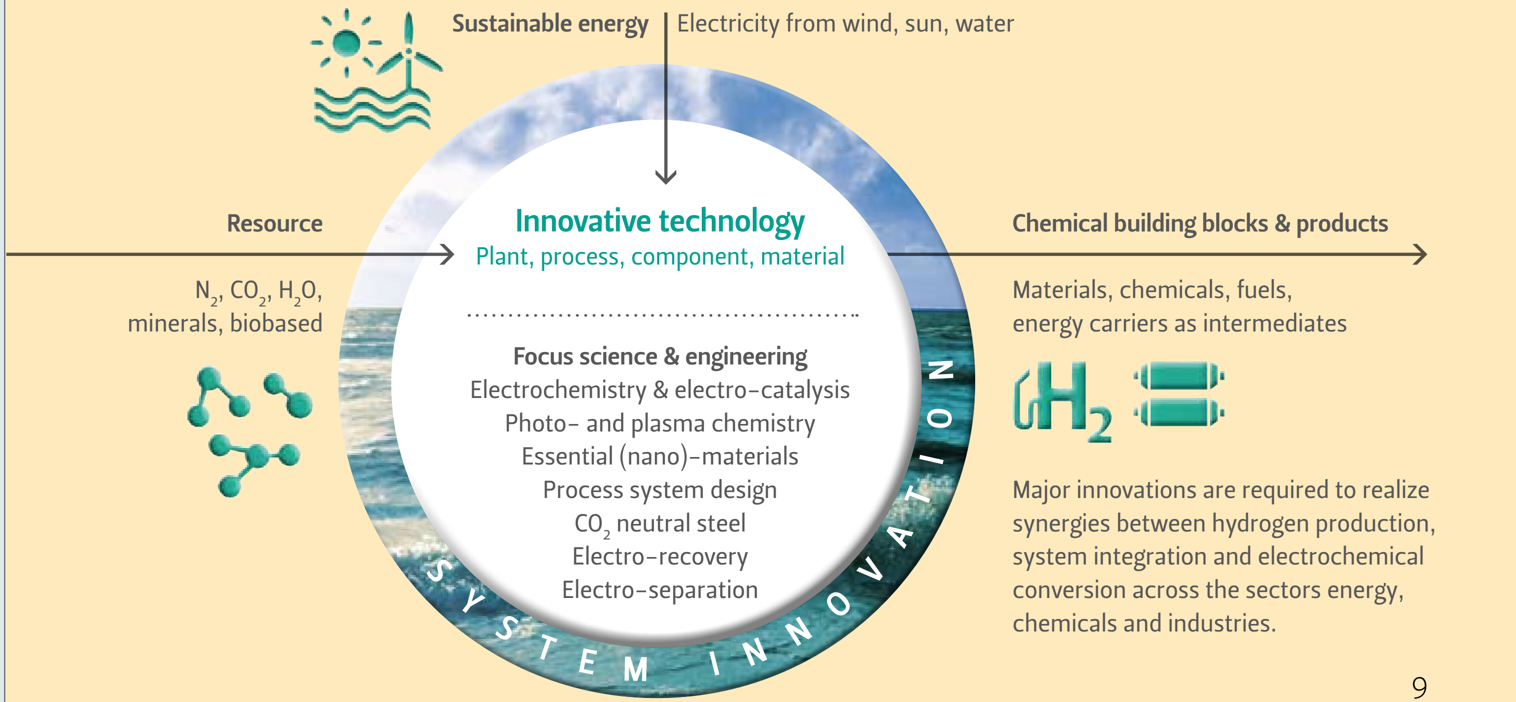
In addition to these 'green electrons', the electrification and shift to renewables also requires major advances in electrochemical conversion and materials technology. Feedstocks need to be converted with sustainable energy and innovative technologies to serve as building blocks for further processing/use (so-called 'green molecules', including but not limited to hydrogen).

Figure 1 · **Global primary energy demand**



Source: Roland Berger

Figure 2 · **Role of hydrogen and synergies with sustainable energy and resources for energy, chemicals and heavy industries**



Germany and The Netherlands: the case for collaboration

The scale and complementarity of their green hydrogen and chemicals ambitions make Germany and The Netherlands natural collaborators. They are frontrunners in global hydrogen and derivatives initiatives, with planned capacities of 240 MW and 350 MW in 2022 respectively (figure 3).

Figure 3 · **Global hydrogen and derivatives initiatives** (>5 MW) Status Q2 2020, not exhaustive

LEGENDA

❶ Indicated capacity
❷ FID and current phase
❸ End application(s)
❹ Consortium partner(s)
❺ Green hydrogen
❻ Green ammonia
❼ Green methanol

Advanced Clean Energy Storage (ACES), US

❶ 25 MW, first phase assumption as part of 1 GW energy storage project
❷ 2022 / Study-feasibility
❸ H_2 to electricity grid
❹ Mitsubichi Hitachi Power Systems, Magnum
❺ Green hydrogen

Power-to-methanol, Belgium

❶ 25 MW
❷ 2019 / Feasibility phase
❸ Chemicals, blended fuels
❹ Inovyn, Port of Antwerp, Engy, Oiltanking, Fluxus, Indaver, PMV
❼ Green methanol

Bécancour Canada

❶ 20 MW
❷ 2018 / Construction
❸ Iron & steel, road
❹ Air Liquide, Hydrog(e)nics
❺ Green hydrogen

Les Hauts de France, France

❶ 100 MW, first phase of 500 MW project
❷ 2020 / Study/feasibility
❸ H_2 to gas grid
❹ Hydrogen Pro, Elplatek, H2V
❺ Green hydrogen

Hyex Chile

❶ 50 MW, first phase of 780 MW electrolyser
❷ N.a. / Feasibility phase
❸ Explosives
❹ Engie, Enaex
❻ Green ammonia

Asian Renewable Hub Australia

❶ 100 MW, first phase assumption of 12 GW project
❷ 2025 / Study/feasibility
❸ Iron & steel, fuel
❹ Intercontinental Energy, CWP, Vestas, Pathway
❻ Green ammonia

GET H2 Germany

❶ 100 MW
❷ 2022, first phase of 780 MW electrolyser / Study/feasibility
❸ H_2 to oil refinery, chemicals
❹ RWE, OGE Nowega

Green HydroChem, Germany

❶ 140 MW
❷ 2021 / Study/feasibility
❸ H2 to gas grid, oil refining
❹ Siemens, Uniper, Terrawatt, The Linde Group, 50 Hertz, Ontras
❺ Green hydrogen

Gothenburg H_2, Sweden

❶ 20 MW
❷ 2021 / Study/feasibility
❸ Oil refining, H2 to electricity grid, power
❹ Vattenfal, Preem
❺ Green hydrogen

Sustainable fuels Denmark

❶ 100 MW, Increase to 250 MW by 2027 and 1.3 GW by 2030
❷ 2021 / Study/feasibility
❸ Steel, chemicals, mobility, ...
❹ Orsted, DFDS Seaways, SAS, Panaplina, DSV, CHP, Maersk
❼ Green methanol

BP Green Hydrogen Netherlands

❶ 250 MW
❷ 2022 / Study/feasibility
❸ Oil refining
❹ Nouryon, Port of Rotterdam
❺ Green hydrogen

H2ermes Netherlands

❶ 100 MW
❷ 2021 / Study/feasibility
❸ Steel, chemicals, mobility, ...
❹ Tata Steel, Nouryon, Port of Amsterdam

Baicheng hydrogen, China

❶ 20 MW
❷ 2022 / Study/feasibility
❸ H2 to gas grid, fuel
❹ Jilin Electricity Power Co, Goldwind, CSIC
❺ Green hydrogen

BP green NH_3 Australia

❶ 20 k tons ammonia p.a.
❷ 2021 / Feasibility phase
❸ TBD
❹ Lightsource BP, BP
❻ Green ammonia

Yara Pilbara Australia

❶ 30 k tons ammonia p.a.
❷ N.a. / Feasibility phase
❸ Fertilizer
❹ Yara, Engie
❻ Green ammonia

Hyport Duqm, Oman

❶ 250 MW, First phase of GW project
❷ 2021 / Study/feasibility
❸ N.a.
❹ Deme
❺ Green hydrogen

Source: Roland Berger

Germany and The Netherlands also lead the European Union in national targets and plans for green hydrogen and green chemicals. Together, they aim to deliver 8–9 GW of energy via hydrogen in 2030, more than 20% of the total EU target of 40 GW. Both countries have already announced dedicated ‘hydrogen valley’ projects, such as Hydrogen Valley Northern Netherlands and the Hydrogen Valley Emscher-Lippe in Germany. Moreover, national investment programs in both countries have been announced (Germany) or are about to be announced (The Netherlands).

Germany’s hydrogen vision can be summarized in three subsequent stages.

2021 — 1 — 2 — 3

1 Lay the foundations for an advanced domestic hydrogen ecosystem by 2023

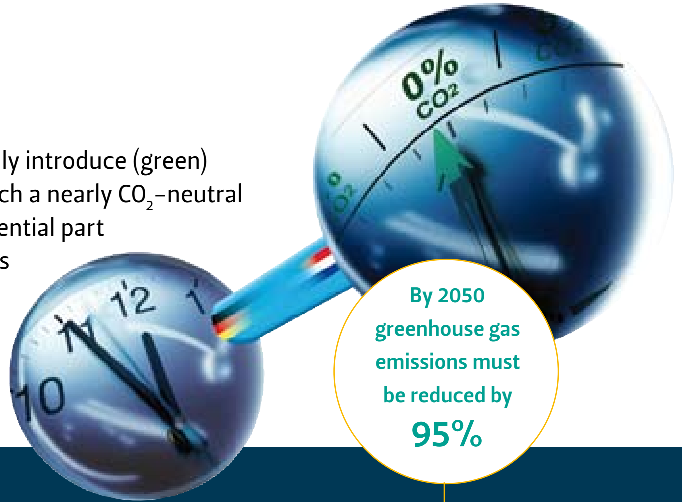
2 Strengthen the domestic hydrogen ecosystem and expand to pan-European by 2030

3 Become the global supplier of state-of-the-art hydrogen technology by 2050

Recent and current policy has focused on setting the parameters, advancing technology readiness level and business case for large-scale commercialization of Fuel Cell Hydrogen, and starting to establish the necessary infrastructure for initial users. June 2020 Germany launched its national hydrogen strategy 2020-2026.
The strategy lists existing government programmes supporting hydrogen technologies. In addition to this, the stimulus package agreed on provides for a further 7 billion euros to be made available for the market ramp-up of hydrogen technologies in Germany and a further 2 billion euros for international partnerships. The strategy includes a 1.4 billion euros National Innovation (subsidy) Programme (NIP) for Fuel Cells and Hydrogen. The NIP kickstarts stage 2, aiming to increase domestic green hydrogen production capacity to 5 GW. This enables large-scale commercial applications, including road- and rail-transport (with ~400 hydrogen refueling sites) and should position Germany as a strong hydrogen player, able to expand across Europe.

The national strategy says Germany's current use of hydrogen equals around 55 TWh. By 2030, the initial increase in demand for hydrogen is expected to occur particularly in the industrial sector (chemicals, petrochemicals and steel) and, to a lesser extent, in transport, as a result of the impetus of the market ramp-up.
The strategy cites other studies suggesting that the demand for electricity-based fuels will increase

Like Germany, the Netherlands plans to systemically introduce (green) hydrogen in transport, heating and industry to reach a nearly CO_2-neutral economy by 2050. It envisions hydrogen as an essential part of a Dutch energy system in which carbon-free gas delivers >30% of the final energy demand.



By 2050 greenhouse gas emissions must be reduced by
95%

The Dutch ambitions have similar timelines.

2021 — 2025 — 2030

to a range of between 110 TWh and 380 TWh by 2050. A committee of state secretaries of affected ministries will ensure implementation of the strategy. In addition, the government will establish a national hydrogen council made up of 25 representatives from business, science, and civil society that will support the state secretary committee. This resembles to some extent the National Hydrogen Programme in The Netherlands. The high-level round table Hydrogen and Green Chemistry in the Netherlands aims to support the national strategy.

For the longer-term, after 2026, German officials indicate that hydrogen will play a decisive role in reaching the CO2-reduction target for 2050, as an energy carrier and storage medium and to defossilize transport and industry. Germany has also set targets to install >1.000 hydrogen refueling sites – including specific sites for (heavy) industry rather than only for transportation and heating – and to further increase the installed green hydrogen capacity to ~10 GW in 2050. Most importantly, Germany has expressed the ambition to become a leading global supplier of hydrogen technology and equipment.

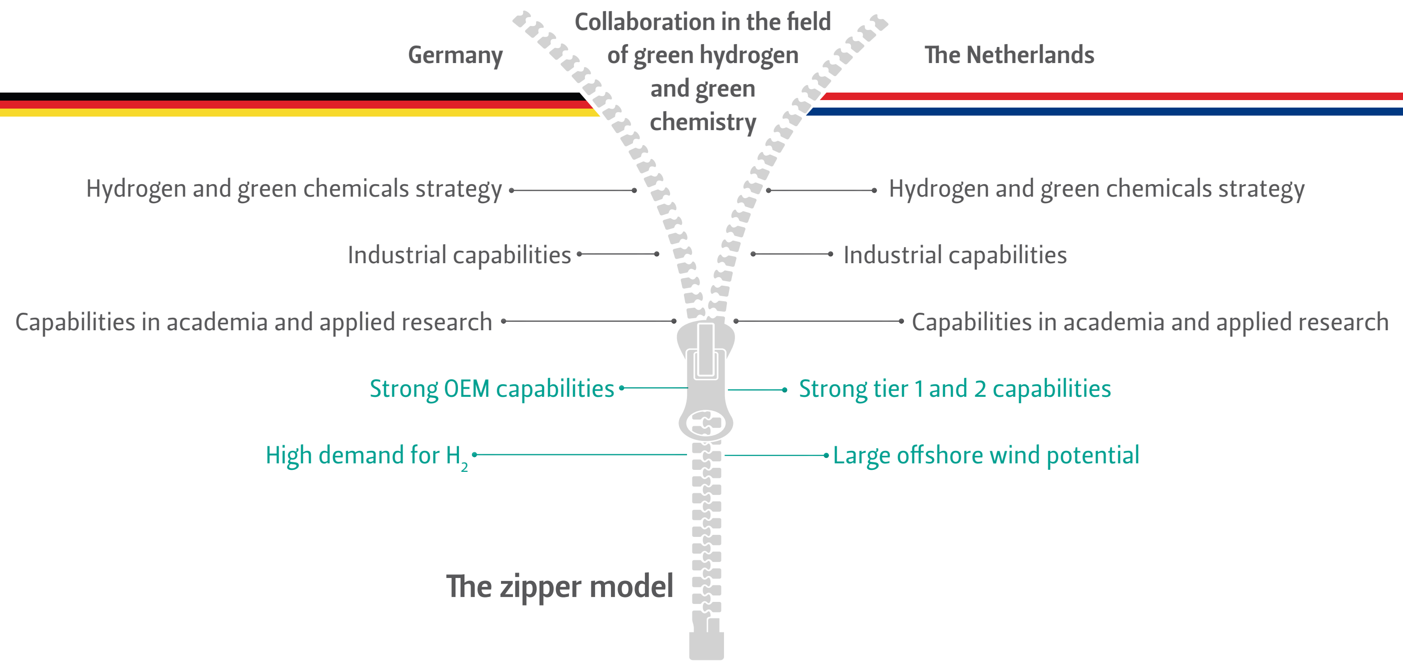


Figure 4 · **German and Dutch actors, partnerships and initiatives [not exhaustive] and interlocking strengths**

Test setup at TNO, The Netherlands

TNO

The Dutch and German ambitions are compatible and complementary. Both have set out strategies that focus on domestic consumption, domestic production and international imports. Both have government departments that drive these strategies and strong capabilities in their respective industries, academic groups, applied research organizations and the public-private partnerships between them (see figure 4).

In addition to these capabilities, Germany has strong OEMs and a high (industrial) demand for hydrogen, and The Netherlands excellent tier-1 and tier-2 suppliers and a large potential of offshore wind for green hydrogen production. Collaboration in the field of green hydrogen and green chemicals – like a zipper being pulled – would interlock and reinforce both countries' strategies, capabilities and particular strengths and enable them to play a leading role in a future European hydrogen economy.

Germany

- Ministry for Economic Affairs and Energy, Ministry of Education and Research
- Excellence Clusters (The Fuel Science Center/RWTH,
- E-Conversion/Munich, Aviation Fuels/Braunschweig)
- 20280 – Transient operation of electrocatalysis
- 2397 – GDEs and the triple phase boundary
- Kopernikus Project Power2X and Project Synergy
- Carbon2Chem
- CO2plus
- InnoEMat
- Cluster4Future
- Living Labs for the Energy Transition (e.g. SmartQuart)
- Energy Research Networks (Hydrogen)
- Energy Transition in the Transportation Sector
- BENIVER
- BMBF/Kohleausstieg
- iNEW integrated value chains
- Electra – Kompetenzzentrum Elektrochemische Verfahrenstechnik (Aachen, FZ Juelich)
- Sci4Climate, In4Climate

BMBF announced January 2021 that 700 million euros will be made available for 3 large hydrogen and green chemicals projects: H2Giga, TransHyDE and H2Mare.

- **H2Giga** – focuses on optimizing the production process of electrolysers.
- **TransHyDE** – investigates the possibilities for hydrogen transport at short and long distances.
- **H2Mare** – works on the production of green hydrogen and other PtX-products from wind directly offshore.

The Netherlands

- Ministry of Economic Affairs & Climate, Ministry of Education, Culture & Science
- Research groups at universities and applied research institutes (based on the annual ECCM conference – about 400 participants)
- Private companies in the field of energy distribution, production and (pure) gas companies, as well as major industrial/chemical companies (a.o. Air Liquide, Nouryon, BASF, DOW, Shell, Orsted, HyET, NedStack, VDL and others) and the port of Rotterdam.
- NWA Energy storage & conversion
- NWO Tenure track ECCM
- NWO Technology Area Electrogas
- TNO Early Research Program Energy Conversion & Storage
- TNO Faraday lab – Production and small-scale pilots for the development of PEM and Solid Oxide Electrolysis
- Several academic institutes in field of ECCM: e-refinery, Center for Multiscale Catalyic Energy Conversion, Dutch Institute for Fundamental Energy Research, Institute for Renewable Energy Systems, Amsterdam Centre for Electrochemistry, J.M. Burgerscentrum
- Several NGOs: Urgenda, Natuur & Milieu, 'Het Groene Brein'
- TKI (Topconsortia Kennis & Innovatie): 'Energie & Industrie', 'Nieuw Gas', 'Chemie' & 'High Tech Systems & Materialen'
- ISPT GW scale project and HydroHub MegaWatt test center
- National public private partnerships: Advanced Research Center for Chemical Building Blocks, Reversible Large-scale Energy Storage consortium, Electrons2Chemical Bonds consortium, CO2 neutral fuels and Solar to Products program, TNO Voltachem, Faraday lab and Field Lab Industrial Electrificiation, Hydrohub, Brightsite

Source: Roland Berger

Areas for collaboration: challenges and technologies

On October 8th 2020, a virtual workshop brought together over a hundred experts from Dutch and German industry, knowledge institutes and governments to identify and discuss common challenges and potential areas for bilateral collaboration (a full list of participants is provided at the end of this paper).

Like other EU countries and most of the world, Germany and The Netherlands committed themselves to reaching net zero emissions in 2050. While that may seem far away, realizing the energy infrastructure and electrochemical conversion and materials technologies needed – including for the production and use of green hydrogen – involves long lead times and huge investments. Nor is the transition only about technology. It also needs the public to accept the urgency and implications and public bodies, incl. governments, to shape regulation to enable and support it.

In concrete terms, reaching net zero emissions in 2050 will require:

- **Immediate and disruptive change**
Transitioning to renewable energy sources is a massive challenge that necessitates a massive transformation. A gradual shift will not achieve the targets set by the Netherlands and Germany, as both have too much CO_2-emissions that must be abated. While setting a target is easy, the roadmap to achieve that target is far more complicated. Many of the crucial infrastructure facilities have a lead time of 15-20 years. This implies that to meet the climate target in 2050, energy infrastructure should be ready by 2035, which means that the transition technology should already be available. Disruptive changes to the system need to be planned now – and there is no time to waste.

- **An inclusive approach to society**
Public discourse becomes extremely important as local populations are affected the most. Communication around costs and potential job losses, as well as new opportunities, should be as open and honest as possible. It is crucial to educate the public on the end situation envisaged and how that will benefit society in general. Getting people to accept new technologies is never easy. It always involves change, uncertainty and trade-offs. That is why it is essential to involve the general public early and give them the tools and time needed to get to grips with and accustomed to the changes to come. The general public supports climate change goals – and this should be leveraged when explaining (new) technology, its role in the energy transition, benefits and risks in a clear, simple and open way.

- **Regulation even more than technology**
Transitions are typically characterized by bottom-up initiatives but at a certain point executive coordination is needed to ramp-up. In addition to industry and academia, governments have a critical role in enabling and encouraging the investment in and implementation of new technologies. Fossil feedstocks are extremely cheap and not easily replaced by green alternatives like hydrogen – especially if environmental costs are not fully priced in. Without proper regulation, permission from local authorities and creation of industrial zones can become painstakingly inefficient. Such examples underscore why it is imperative that governments provide the regulatory frameworks and incentives (including fiscal stimuli where needed) to create a level playing field for carbon-free alternatives – and that they act fast and start now. Regulation, not technology, will determine the speed and success of the energy transition.

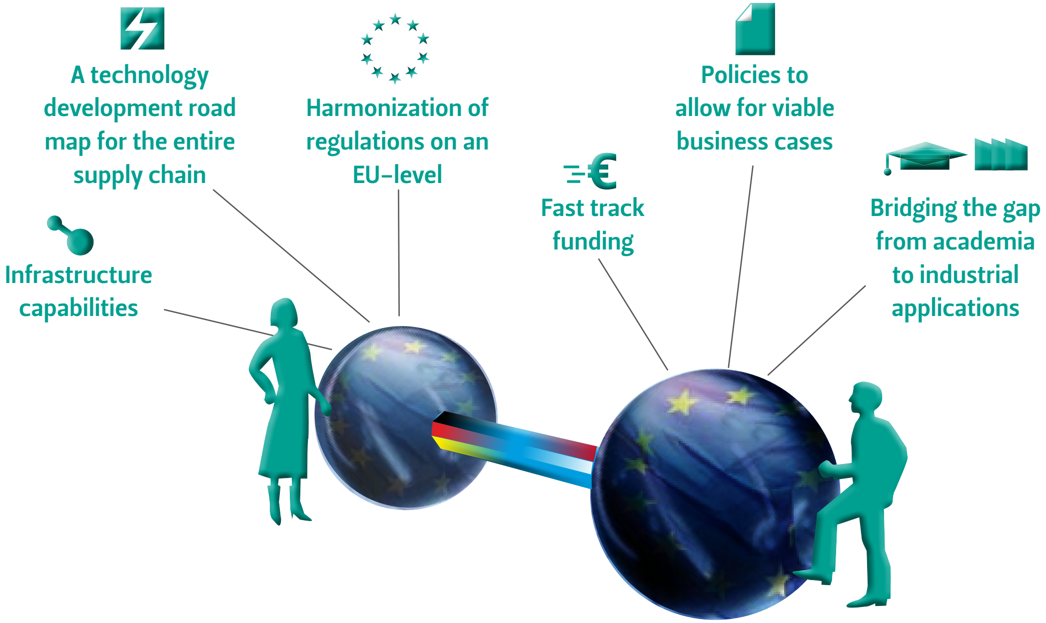
To achieve their emissions reduction targets, the Dutch and German governments should develop a roadmap – ideally joint, but at least aligned – to guide the energy transition and electrification of processes and give industry and consumers the perspective, parameters and incentives they need.


TNO

There is also a broad scope to collaborate on technological challenges, both specific and general. Both countries' strategies for green hydrogen and green chemicals focus on domestic consumption, international imports and the production of electrolysis equipment. Both have unique innovation ecosystems, chemical producers and industrial clusters, and a fast growing supply of renewable energy – not to mention ambitions that complement and can reinforce each other. Bilateral collaboration will also set an example and position both countries for other multilateral alliances all over Europe.

In the workshop of 8 October 2020, the Dutch and German experts participating identified potential areas of bilateral collaboration along five technological areas, summarized in table 1.

In addition to these technology specific areas of cooperation, the participants identified some general areas for attention:



These general and technology specific areas should be the basis for collaboration efforts – starting with pilots and building up to structural.

Table 1 · Areas for collaboration

Electrolysis	Electrosynthesis	Material and catalysis	Engineering / manufacturing of cell equipment	System design and integration
Hydrogen storage	Alternative anode reactions	Genesis, stability and degradation	Innovative sustainable materials	Large scale demo projects
Next generation of electrolyzers	Analysis of electrochemical reaction systems	CO_2 capture and direct conversion	Recycling/reducing of scarce materials	Creation of business model/ markets to allow scale-up
R&D on catalyst materials and membranes	Broadening research in areas other than CO_2 -related	Novel material development	Electrolyzer cost reduction and efficiency increase	Value chain efficiencies
Electrolysis cost reduction	Electrolyte free electrosynthesis	Large data mining and analytics	Mass series manufacturing	Safety considerations
P2X technologies	Benchmarking against thermochemical processes	Synchrotron radiation	Integrating electrolysis processes with renewable energy generation	Solid and reliable scenarios on the future use of industry
←········· System integration ·········→				
←····· Socio-economic aspects ·····→				

Source: Roland Berger

Recommendations for national governments

With the input from the workshop, the bilateral committee formulated six recommendations:

1. **Bring together complementary expertise in bilateral projects**, starting with pilots and culminating in structural collaboration in electrolysis, electrosynthesis, material and catalysis, engineering and manufacturing of cell equipment, and system integration (on topics summarized in the table in the previous chapter).
2. **Develop a (joint/aligned) energy transition roadmap** to provide stable investment conditions for companies and consumers, supported by the necessary regulatory frameworks.
3. **Align national programmes** ('zipper model').
4. **Pursue collaboration on key enablers**, including a technology roadmap for the entire supply chain, infrastructure capabilities, harmonization of regulations (on the EU level), fast track funding, policies to allow for viable business cases and bridging the gap from academia to industrial applications.
5. **Intensify R&D collaboration between The Netherlands and Germany** on related themes, amongst others by sharing unique research infrastructure and testing facilities, building strong multilateral alliances in European collaborations, bolstering a Dutch-German research community, and encouraging collaboration across sectors (energy, chemicals, hightech) and disciplines (electrical engineering, chemistry, physics, process technology, social and behavioural sciences, economics and management studies, ...).
6. **Organize innovation missions and connect new supply chains**.

Workshop participants and defined focus areas

Lydia Albrecht, KIT Karlsruhe

Energy Lab 2.0, Germany

Workshop on electrolysis

PARTICIPANT LIST

Name	Country	Institute/company	Expertise
Gesine Arends	Germany	Projektträger Jülich	Research programmes on energy and hydrogen
Thomas Goergen	Germany	Covestro Deutschland AG	Innovation networks
Volker Göke	Germany	Linde Technology	Scouting Manager Transformational R&D
Jürgen Kintrup	Germany	Covestro	Electrolysis
Jochen Seier	Germany	Forschungszentrum Jülich	Development and system integration of energy storage
Wolfgang Schuhmann	Germany	Ruhr-Universität Bochum	Elektroanalytik & Sensorik
Thomas Turek	Germany	TU Clausthal	Chemical Reaction Engineering
Vivien Wilkens-Mallach	Germany	German Embassy The Hague	
Joop Gilijamse	Netherlands	Embassy of The Netherlands in Germany	Innovation, Technology and Science
Lennard van der Burg	Netherlands	TNO	Program development manager green Hydrogen
Mikhail Tsampas	Netherlands	DIFFER	Catalytic and Electrochemical Processes for Energy
Ulco Vermeulen	Netherlands	Gasunie	Director Participations & Business Development
Marco Waas	Netherlands	Nouryon	Director RD&I and Technology Industrial Chemicals
Hans van der Weijde	Netherlands	Tata Steel	Director programmes
Ellart de Wit	Netherlands	HyGear	Industrial gas supply
Marle Zijlstra	Netherlands	Ministry of Economic Affairs & Climate Policy	Policy Officer Energy Innovation

FOCUS AREAS

Technology, R&D
- Fundamental R&D, catalyst materials, membranes, etc.
- Next generation of electrolyzers, co-existence of alkaline, PEM, SOEC (CO_2 electrolysis)
- Hydrogen storage (cryogenic systems, etc.)
- P2X technologies
- Infrastructure: transport and distribution, system integration
- Fast innovation tracks into application – Bridging acedamics and industry

Projects/deployment
- Knowledge exchange (small and GW-scale)
- Joint projects: technological aspects of H_2 (colour neutral)
- Sharing of risks and R&D spent (company-level, PPPs)

Supply chain ramp-up
- Synchronization of supply-demand needed, production capacity no limitation
- Compontents and materials selection to ensure security of supply

Policies & regulation
- Harmonization of regulations (safety, public acceptance)
- Power taxation, network charges
- Establish policies to allow viable business cases

Funding
- Lower complexity of DE/NL, simple scheme, fast track, concrete scope
- Innovation focus
- Networking, suitable partners
- Creating visibility

Workshop on electrosynthesis

PARTICIPANT LIST

Name	Country	Institute/company	Expertise
Roland Dittmeyer	Germany	KIT	Micro Process Engineering
Rüdiger Eichel	Germany	FZ-J	Materials and processes for electrochemical storage
Frank Kensy	Germany	b.Fab	Conversion of CO2 and hydrogen (H2)
Siegfried Waldvogel	Germany	Universität Mainz	Electrochemistry
Ulrike Krewer	Germany	Karlsruhe Institute of Technology	Analysis of electrochemical cells and electrodes
Harald Pielartzik	Germany	Verband der Chemischen Industrie e.V.	Innovationsmanager Chemie
Marta Costa Figueiredo	Netherlands	Eindhoven University of Technology	Electrochemistry
Earl Goetheer	Netherlands	TNO	Sustainable Process & Energy Systems
Marc Koper	Netherlands	Leiden University	Electrochemistry
Ruud Ommen van	Netherlands	Delft University of Technology	Dispersed multiphase reactors
Richard van de Sanden	Netherlands	ECCM	Plasma physics & chemistry
Ando Kuypers	Netherlands	Brightsite center	Project manager
Moritz Schreiber	Belgium	Total	CO2 electro-conversion
Bas Warmenhoven	Netherlands	Ministry of Economic Affairs & Climate Policy	Senior Policy Advisor Innovation Policy

FOCUS AREAS

Alternative anode reaction
- Identification of platform molecules for anode oxidation to scale up and to direct further research
- Identification of applicable catalysts
- Identification of technology bring these components together

Electrochemical reaction
- Multiphase electrochemical reactor system
- Compatibility of anode and cathode
- Process system engineering: Downstream processing (especially separation) and feed preparation (CO_2 capture process)
- Electrochemical reaction at high temperatures
- Standardization (and further analysis) of gas diffusion electrodes and performance

Broadening research
- Diversify research for application in areas other than CO_2 and CO_2 related issue
- Define groups of renewable building blocks for feedstock types

Technology
- Bridge gap from lab to practice
- Scalability w.r.t. electricity feed and use of critical materials
- Supporting electrolyte free
- Benchmarking against thermochemical processes

Workshop on materials and catalysis

PARTICIPANT LIST

Name	Country	Institute/company	Expertise
Bernd Bauer	Germany	FumaTech	Research programmes on energy and hydrogen
Enrico Barsch	Germany	Bundesministerium für Bildung und Forschung	Innovation networks
Nino Berta	Germany	Climeworks Deutschland	Scouting Manager Transformational R&D
Tobias Gärtner	Germany	Fa. ESy-Labs GmbH Regensburg	Elektrolysis
Roel van de Krol	Germany	Helmholtz Zentrum Berlin	Head of the Institute for Solar Fuels
Carina Faber	Belgium	Engie	Policy Officer Energy Innovation
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Ning Yan	Netherlands	University of Amsterdam	Policy Officer Energy Innovation
Walter Leitner	Germany	Max Planck Institute for Chemical Energy Conversion, RWTH Aachen	Elektroanalytik & Sensorik

FOCUS AREAS

Genesis, stability and degradation
- New materials catalytic or membrane
- More research on alkaline
- Requires lot of inductive science

Synchrotron radiation
- Access and application of in-site studies
- Access to synchrotron radiation sources

Novel materials
- High throughput studies approach to develop novel materials

Electrolysis cost reduction
- Focused effort on reducing electrolysis cost thorugh R&D
- Alternative to iridium oxide

CO_2 capture and conversion
- Capture CO_2 using bipolar membranes
- Testing of CO_2 in real conditions
- Potential to use carbonates to capture CO_2

Data mining and analytics
- Large data processing
- Adapting capabilities in other sectors to materials and catalysis

Workshop on engineering & manufacturing of cell equipment

PARTICIPANT LIST

Name	Country	Institute/company	Expertise
Ulf-Peter Apfel	Germany	Fraunhofer Umsicht	Elektrochemie
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Sander ten Hoopen	Netherlands	Hydron Energy	PEM electrolysis
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Guido Mul	Netherlands	Twente University	Photocatalytic synthesis
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John van der Schaaf	Netherlands	Eindhoven University of Technology	Chemical reactor engineering
Robert Thijssen	Netherlands	Ministry of Economic Affairs & Climate Policy	Chemistry

FOCUS AREAS

Electrolysis
- Great reduction in costs of electrolyzer equipment
- Capacity increase of electrolyzer from 5 MW to 2 GW
- High temperature electrolysis for CO from CO_2 – 700 degrees
- Best geometry for mass transport
- High temperature hydrogen technology to integrate with nuclear

Mass series manufacturing
- Roll-to-roll manufacturing of membrane electrode assemblies, low-cost automated assembly of components, standardized and automated manufacturing technology
- High-volume production technology for electrolyzer equipment parts
- Modular stacks
- Standardization of components

Supply chain roadmap
- Learn from the automotive sector – to understand relation between cost and stack size – scale vs numbers – experts in automotive could give insights
- Reach out to OEMs and invite them to join in building a roadmap

Integrate renewables generation and electrolysis processes
- Explore technology to feed DC directly into electrolyzer to save cost
- Control and stabilize voltage in large electrolysis systems
- Adapt technology to intermittent renewables

Innovative, sustainable materials
- Advanced polymeric membranes, steel foils with integrated coating materials, Platinum Group Metal (PGM) -free catalysts and 3D structuring thereof
- Solutions in materials from low-TRL research? 3D printing for prototype testing
- Recycling/reducing scarce materials based on end-of-life
- Improvements possibilities in membranes

Workshop on system integration & design

PARTICIPANT LIST

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Gerard van Rooij	Netherlands	Maastricht University	Sustainable plasma chemistry
Ronald Wolf	Netherlands	Shell	New energy innovation technology – electrical and electronic manufacturing

FOCUS AREAS

Scale-up of electrolysis

- Initiate several large scale demo projects which will help tackle the issues around scale-up
- Collaborate between TSOs/ DSOs, as an open market and a backbone is required.
- Both smaller and larger electrolysis projects and imports need to be able to feed in into this
- Safety considerations and implications, also looking at size & location of e.g. electrolysis and transport modes (also shipping incl. social acceptance)

Infrastructure

- Coordinate efforts around efficient use of the infrastructure and not only on adding additional capacity incl. cross-border and across electricity & gas infrastructure
- For this, solid and reliable scenarios on the future use of industry will be needed

Value chain efficiencies

- Study full value chain efficiencies.
- Not only looking at a gaseous hydrogen network, but also alternatives for e.g. for last mile distribution.
- Fair comparisons taking into account a full value chain view

Colophon

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