GREEN HYDROGEN AND POWER-TO-X

GERMAN DEMAND MEETS DANISH SUPPLY

Analysis

September 2022

AHK 1992 2022 30
Dansk-Tysk Handelskammer
Deutsch-Dänische Handelskammer

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1. Introduction

Climate Change is one of the most pressing issues of our time. There is an urgent need to drastically reduce greenhouse gas emissions in the near future. **Hydrogen** and **Power-to-X (PtX) technologies** play an increasingly important role in mastering this challenge.

Denmark, **Germany**, and the **five northern German** states have all released **strategies regarding the future of green hydrogen and PtX technologies**. The overall goal of all strategies is the decarbonisation of industry, mobility, and other sectors.

- The Northern German and the German strategy focus on (green) hydrogen and the direct use of it
- The Danish strategy has a wider focus on PtX technologies

The German Government describes hydrogen as one of the key elements in the energy transition. **Germany's production capacity of renewable energy is limited**. It is therefore dependent on importing renewable energy sources – including (green) hydrogen.

International cooperation and partnerships are vital for a successful energy transition. Germany and Denmark are not only geographical neighbours, but partners in many regards. Denmark has a large production of wind and green power to use for producing green hydrogen and sustainable fuels. The demand for hydrogen in Germany will significantly increase in the upcoming years. **Increased cooperation between Germany and Denmark therefore seems to be a no-brainer**.

2. Power-to-X and hydrogen

The PtX technology

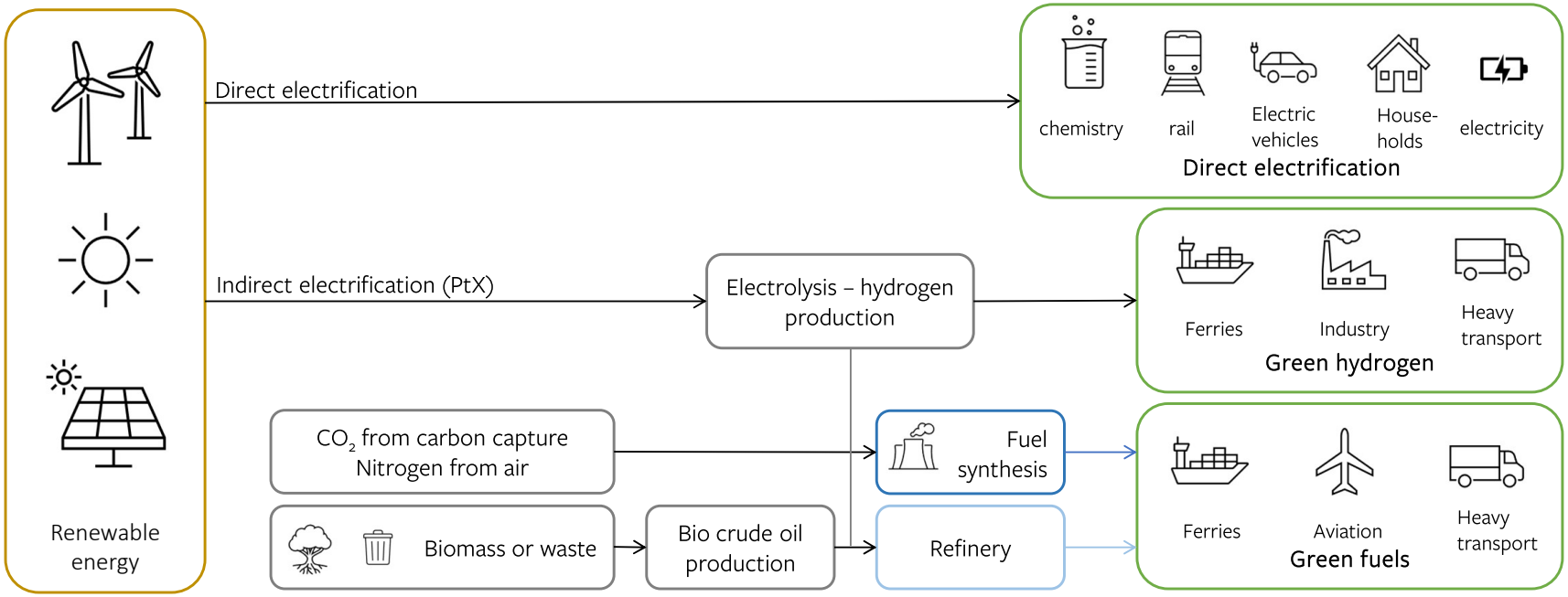
PtX uses electricity coming from renewable sources, where the X designates the substance produced.

The core technology behind PtX is called **electrolysis**, where electricity is used to split water into its elements hydrogen and oxygen. Besides hydrogen, **hydrogen-based substances (e.g. ammonia, methanol, and methane)** are produced by using PtX technologies as well. **These substances can be used as sustainable fuels in ships, aircraft, trucks, and heavy industry**.

The following figure shows how renewable energy can be used for **direct and indirect electrification** using PtX technologies:

PtX has the potential to help meet global climate goals. But **it is not in and of itself environmentally friendly and sustainable. Ambitious and binding sustainability rules** must apply from the start to make PtX truly climate neutral:

- PtX must be produced from additional green power plants
- It should be produced in countries where water shortages are not an issue
- The necessary CO2 must be taken directly from the atmosphere or from processes using sustainable biomass
- The ecological and social effects of PtX production must be measured through sustainability monitoring



1 - How PtX can contribute to a greener future[1]

Hydrogen: Why the hype?

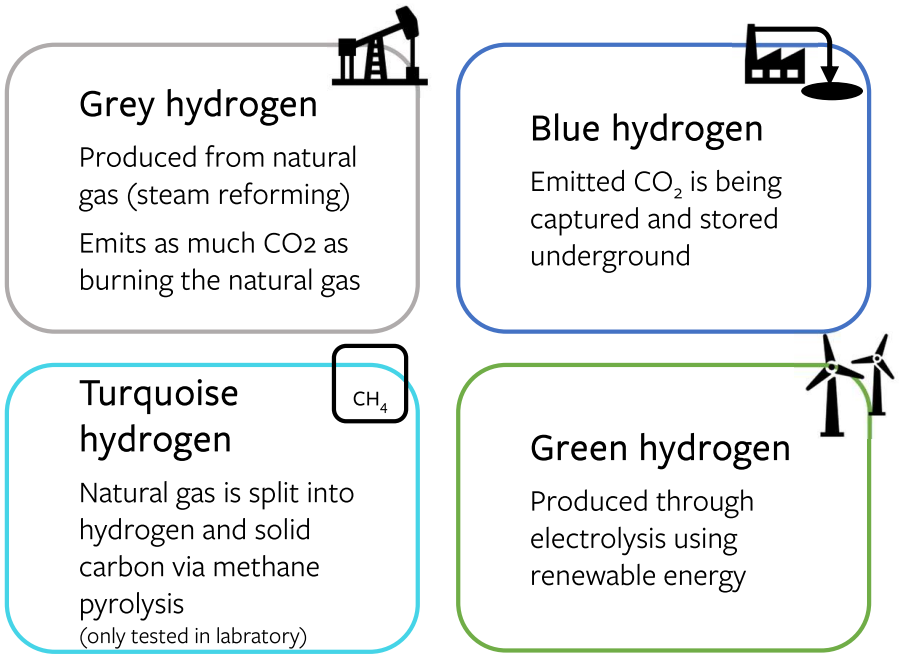
Hydrogen is a sector-coupling fuel and a flexible energy carrier. Its **benefits** are numerous:

- **Storage** of excess electricity from windy regions (on-/offshore)
- **Decarbonisation** of the **industrial sector** (steel, chemical, and cement)
- **Decarbonisation** of the **aviation**, **shipping**, and **heavy weight transport** sector

Today, almost all hydrogen production is based on fossil fuels such as coal and natural gas.

Only green hydrogen is sustainable in the long term. It is however very likely that **especially blue hydrogen will play a role in the transition phase from grey and brown hydrogen to green hydrogen**.

Hydrogen is often categorised into colours based on its production method:



2 - Colour categorisation of hydrogen

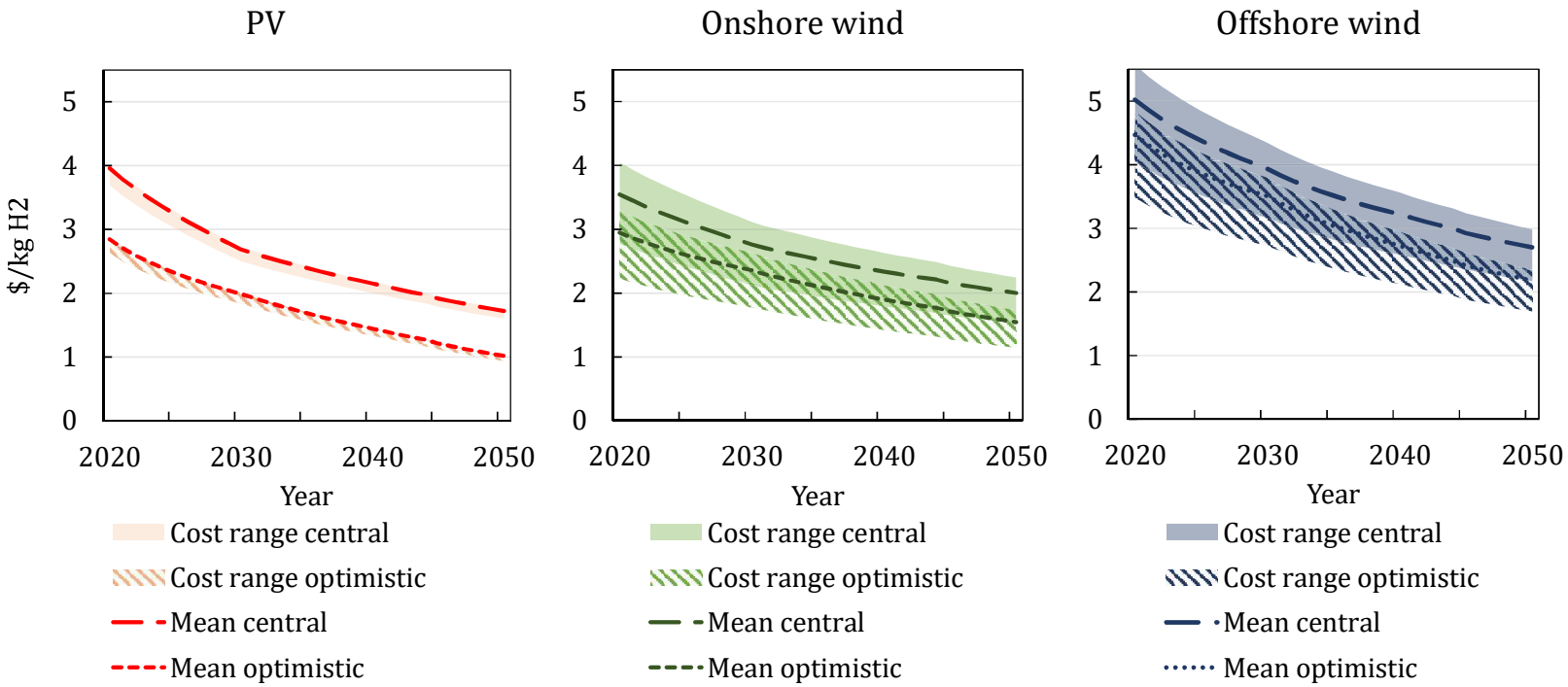
German-Danish Hydrogen Network

The German-Danish Chamber of Commerce has launched the German-Danish Hydrogen Network. It is an initiative for transparency and cross-border cooperation between Germany and Denmark. It is designed to make players visible and foster contacts between companies to increase cooperation. We list projects, events, actors, studies, and strategies and provide information on German and Danish issues with a special focus on cross-border projects. The network is free to join for any organisation related to the field of hydrogen. **You can find more information and apply for a membership on the** Network's website.

Economics of green hydrogen

Global production and supply costs of hydrogen produced with renewable energies will decrease in the coming decades. A study conducted by the Institute of Energy Economics at the University of Cologne shows a significant cost decline in the price per kilogram of hydrogen.

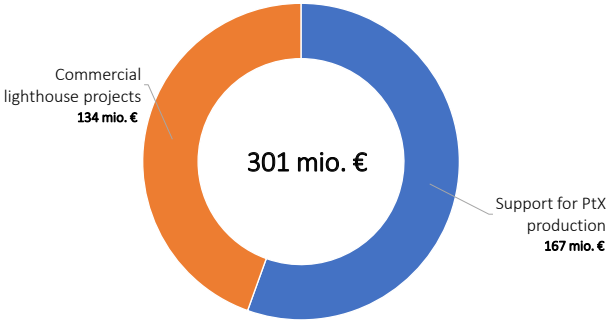
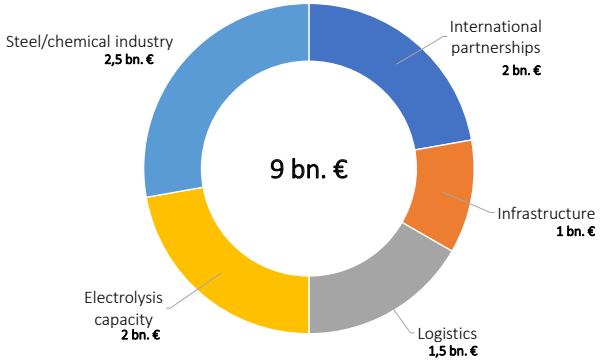
The results suggest that natural gas reforming with carbon capture and storage will be the most cost-efficient low-carbon hydrogen production in the medium term (until 2030). **In the long run (until 2050), hydrogen production from renewable sources could become competitive if capital costs decrease significantly**[III].



3 - Cost ranges of renewable energy sources hydrogen production

Source: EWI: Estimating Long-Term Global Supply Costs for Low-Carbon Hydrogen, p. 14[II]

3. Hydrogen strategies in comparison

	Northern Germany (Bremen, Hamburg, Mecklenburg-Vorpommern, Niedersachsen, Schleswig-Holstein)	**Denmark**	**Germany**
Date of release	07.11.2019	15.03.2022	10.06.2020 (will be updated by the end of 2022)
Budget	(see Germany's strategy)	 Commercial lighthouse projects (in Danish)	
Funding schemes	(n.a.)	• **REACT-EU initiative/Just Transition Fund**: 46 mio. €[IV] • **IPCEI** (two projects): 114 mio. €[V] • **EUDP**[1] and **DEA**[2] energy storage funding pool: 54 mio. €[VI]	• Funding programme **H2 Global**: 900 mio. €[VII]: Support of hydrogen projects outside of the EU that import electricity into the EU • **IPCEI** (62 large-scale projects): 8 bn. € (BMWK[3], BMDV[4], Bundesländer)[VIII] • "Reallabore der Energiewende": up to 15 mio. € per partner (BMWK)[IX]
Planned electrolysis capacity	(see Germany's strategy)	4 - 6 GW	5 GW (the national goal has been raised to 10 GW by the new German Government in its Coalition Agreement)

1 Energy Technology Development and Demonstration Programme
2 Danish Energy Agency
3 Federal Ministry for Economic Affairs and Climate Action
4 Federal Ministry for Digital and Transport

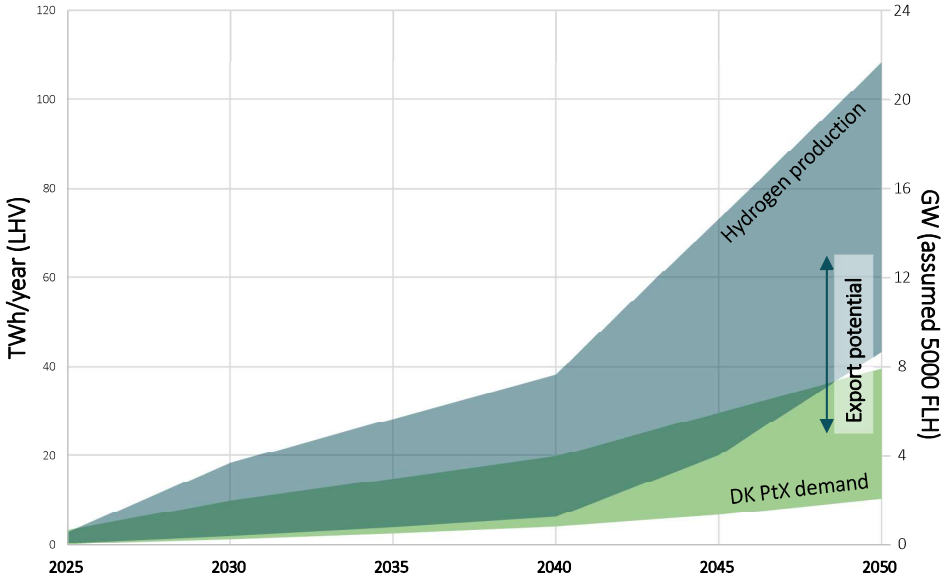
Goals and actions			
	General		
	• Green hydrogen economy in Northern Germany by 2035 • Supply mostly all customers interested in green hydrogen	• PtX as a **contributor to the realisation of the Danish Climate Act** • Push for ambitious, pan-European requirements for CO_2 intensity reduction targets • promote **green transition in the transport and industrial sectors**	• Taking **global responsibility** for the reduction of greenhouse gases • Hydrogen as an alternative energy source • Make hydrogen competitive against fossil fuels
	Regulatory framework and infrastructure		
	• Create **attractive framework conditions** for companies to settle in Northern Germany • Establish a **joint marketing strategy** • **Optimise consent processes** for hydrogen plants by 2022 • Technology- and infrastructure-related funding programmes should always allow for the funding of hydrogen projects	• Set a **regulatory framework and infrastructure** in place to allow PtX to perform on market terms in the long run • Create the necessary framework in legislation and the purpose provision to ensure that Energinet and Evida can own and operate hydrogen infrastructure	• Continuously **improve framework conditions** and take up current developments • Further **develop and secure quality infrastructure** for hydrogen production, transport, storage and use; create trust
	Technical aspects		
	• Develop **hydrogen-hubs** that pool several segments of the hydrogen value chain by 2025 • **Strengthen professional expertise** on the topic of hydrogen by 2025	• Improve the **integration** between PtX and the Danish energy system • Provide the **option for geographically differentiated consumption tariffs** • Create an **application-based scheme** for establishing direct links between major electricity consumers and electricity producers	• **Market development for hydrogen technologies** in Germany • Make hydrogen sustainable as a basic substance for industry • **Support science and train professionals**

	Cooperation		
	• States of Northern Germany will cooperate and express a joint opinion towards others • Develop **synergies through cooperation** with neighbouring regions by 2025	• Be able to **export PtX technologies** and products • Create the **framework for a hydrogen infrastructure** that can be linked to a common European infrastructure	• Ensure **worldwide market opportunities for German companies** • Understand global cooperation as an opportunity • Enable **import** of hydrogen to Germany • Develop a **transport- and distribution infrastructure** • Establish international markets, support mechanisms, and cooperation for hydrogen
Governance	• Working group "**Norddeutsche Koordinierungsgruppe Wasserstoff**": Organisation and coordination of the implementation process and the political communication between the Northern states	• Establish a **PtX task force** to support a Danish hydrogen market and infrastructure (7,6 mio. €) • **PtX secretariat** as part of the task force to assist project developers and authorities with guidance on permitting procedures etc.	• **Committee** that consists of secretaries of state to accompany the activities of the NWS and reevaluate the strategy after three years • **National Council for Hydrogen** that consists of 26 experts from economy, science, and civil society • **Control centre for hydrogen** that supports the National Council with the implementation of the strategy and monitors the national hydrogen strategy
Hydrogen infrastructure	• **Infrastructural funding programmes** should make hydrogen projects possible • part of the gas infrastructure can be **repurposed** to transporting hydrogen • necessary development of a **filling station network** (approx. 250 stations in Northern Germany)	• Possibility of establishing a Danish hydrogen infrastructure • **Necessary framework** must be created to make it possible for Denmark to establish a hydrogen infrastructure for transporting hydrogen in pipes and for underground storage • **Hydrogen infrastructure to neighbouring countries** (e.g. Germany) can support Denmark's ability to contribute to decarbonisation at the European level	• Germany has a **well-developed gas infrastructure** • Transport and distribution infrastructure will be further developed • Part of L-Gas natural gas system available for H2 • **Expansion and extension of dedicated hydrogen networks**

Large export potential on the Danish side

Exporting hydrogen would make it possible for Denmark to export more green energy. A survey among Danish companies in the PtX value chain conducted by Rambøll shows that **many companies expect a Danish export potential of PtX of more than 2 billion € in 2030**. Hydrogen supply in Denmark is expected to surpass the demand[X]. This can make Denmark a net-exporter of hydrogen. A pre-feasibility study for a Danish-German Hydrogen Network by Gasunie and Energinet predicts an export potential of up to 28 TWh in 2040.

Danish production of wind energy, which can be used to manufacture green hydrogen, **will only increase in the coming years**: Two energy islands in the North Sea and the Baltic Sea are currently being planned. Vindø shall have a capacity of up to 10 GW in the long term. The second energy island on Bornholm will provide up to 3 GW of offshore wind energy.

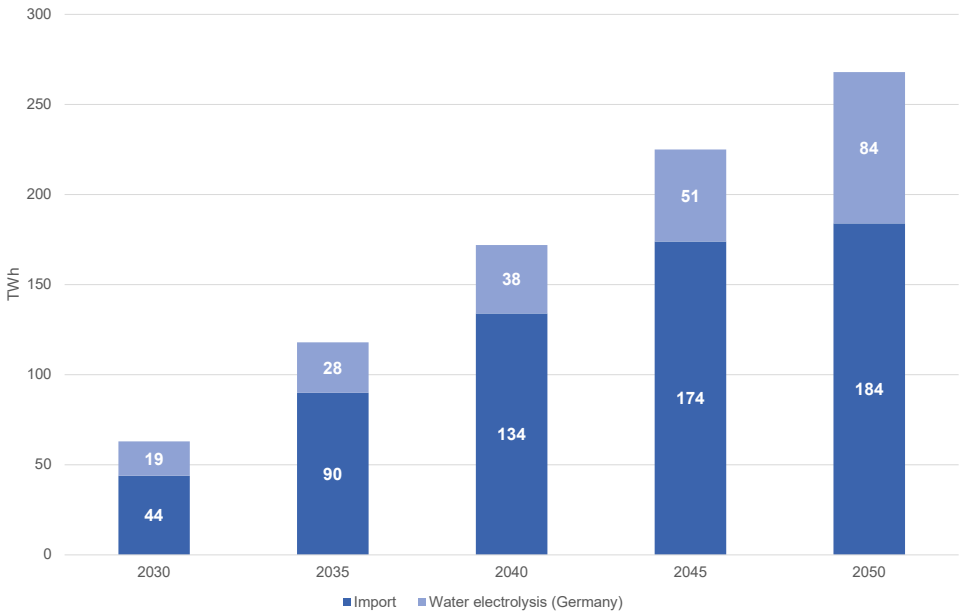


4 - Danish export potential of green hydrogen

Source: Gasunie/Energinet: Pre-feasibility Study for a Danish-German Hydrogen Network, p. 14[XI]

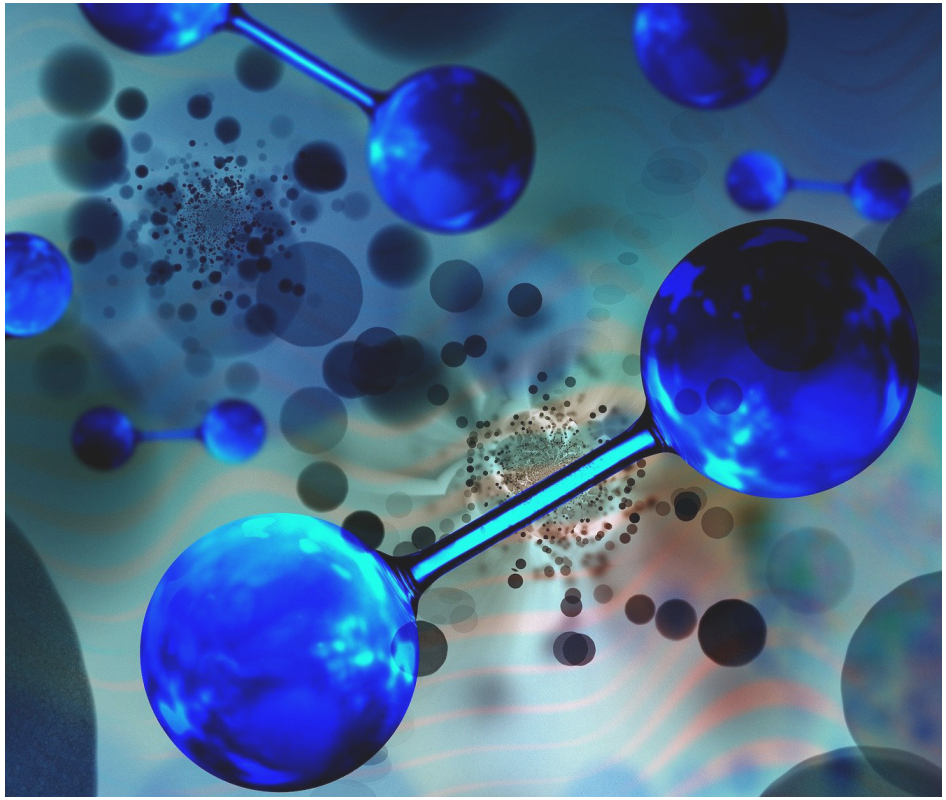
Collaboration needed

The export of energy can be beneficial for the climate as it reduces the need for power plants in other countries. **The potential for renewable energy development in Germany is limited**. The import of energy carriers – with an emphasis on hydrogen and synthetic products – will therefore play an important role in the future. A study by Agora Energiewende predicts a hydrogen demand of about 270 TWh by 2050 in Germany. **Only 31 % of needed hydrogen will be produced in Germany, the remaining 69 % will have to be imported**. Even though a 30 GW Offshore Hydrogen production is included in 2022 novel Windenergie-auf-See-Gesetz, large imports to Germany will still be needed.



5 - Germany has to import a large share of its hydrogen
Source: Prognos, Öko-Institut, Wuppertal-Institut (2020): Klimaneutrales Deutschland, p. 29[XII]

Expert's opinions that were collected during a Delphi study by the Copenhagen Institute for Future Studies and Business Finland indicate that the hydrogen market might never be a transatlantic one.
The future global hydrogen market will most likely be a regional one – underlining the importance of cross-border cooperation between geographical neighbours.



5. Actors

Germany

Category	Name	Profile	More information
Business organisations	Bundesverband der Energie- und Wasserwirtschaft (BDEW)	BDEW represents some 1,900 companies from the sectors power, natural gas, renewable energies, e-mobility, energy grids, and water.	• Best practice examples: Hydrogen in the energy economy (in German)
	German Hydrogen and Fuel-Cell Association (DWV)	DWV is the umbrella organisation in Germany for all concerned with the general application of hydrogen as an energy carrier. DWV advocates that hydrogen should be produced from renewable energies.	• Position paper regarding the National Hydrogen Strategy (in German) • Expert commission H2Global Foundation
Companies	ArcelorMittal	ArcelorMittal is an international steel company. The ArcelorMittal steel plant in Hamburg is already using grey hydrogen for its steel production. Under IPCEI funding, the plant will be transformed to use green hydrogen in the future.	• Hydrogen steel plant Hamburg (in German)
	BASF	The chemical company BASF plans to use turquoise hydrogen to reduce its CO_2 emissions. Turquoise hydrogen is produced with renewable energies out of methane instead of water.	• Clean hydrogen at BASF • BASF's position on hydrogen
	E.ON/Hansewerk	E.ON is one of Europe's largest operators of energy networks and energy infrastructure. E.ON is the majority shareholder of Hansewerk AG. In 2020, Hansewerk started a field test to operate a combined heat and power plant with green hydrogen in Hamburg.	• Hydrogen BHKW Hamburg (in German)
	RWE	RWE is a German energy supply group. RWE is currently running 30 green hydrogen projects with several partners.	• Hydrogen at RWE (in German)
	Salzgitter AG	Salzgitter AG is a German steel manufacturer. With their programme "SALCOS", Salzgitter AG analyses, how hydrogen can be used to reduce CO_2 in the steel production process.	• Salzgitter Low CO_2 Steelmaking (SALCOS)
	Siemens Energy	Siemens Energy is an electrical and power engineering manufacturer and represents the energy part of the Siemens group. Among others, Siemens Energy produces electrolysers for electrolysis plants. Together with its subsidiary Siemens Gamesa the company is adapting the world's most powerful offshore wind turbine to integrate an electrolysis system seamlessly into its operation.	• Hydrogen solutions at Siemens Energy • Green Hydrogen project in the Middle East

	Thyssenkrupp	Thyssenkrupp is an international group of companies comprising largely independent industrial and technology businesses and employing more than 100,000 people. Thyssenkrupp can produce electrolysis cells with an output of 1 GW annually.	• Hydrogen at thyssenkrupp • 2 GW electrolysis plant for NEOM • STEAG and thyssenkrupp steel (in German)
Networks, alliances, others	Erneuerbare Energien Hamburg (EEHH)	EEHH is an industry network for future energies and offers interested stakeholders a platform for networking and information. It is part of many hydrogen projects like the "Hamburg Green Hydrogen Hub" and "HH2E".	• Sector coupling and hydrogen at EEHH • German Renewables Award
	German-Danish Hydrogen Network	The German-Danish Hydrogen Network is an initiative for transparency and cross-border cooperation between Germany and Denmark by the German-Danish Chamber of Commerce. It is designed to make players visible and thereby foster contacts between companies and thereby cooperation.	
Public entitites	Germany Trade and Invest (GTAI)	GTAI is the economic development agency of Germany. It is the first port of call at the federal level for foreign businesses that would like to learn about investment possibilities in Germany.	• GTAI Information on green hydrogen
	Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie GmbH (NOW GmbH)	NOW GmbH is a state-owned company and accepts contracts in the field of sustainable mobility and energy supply from federal ministries. NOW GmbH was founded in connection with the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP).	• Projects at NOW GmbH • Funding finder
	Wasserstoff-Gesellschaft Hamburg	Wasserstoff-Gesellschaft Hamburg has been building bridges between politics, science, and industry for over three decades. It is working together with stakeholders from the metropolitan region of Hamburg to strengthen the role of hydrogen as a sustainable energy carrier.	• Studies commissioned by Wasserstoff-Gesellschaft Hamburg (in German) • Heinz and Joachim Gretz Science Price (in German)

Universities, think tanks	Agora Energiewende	Agora Energiewende is a think tank that develops evidence-based and politically viable strategies to advance the goal of climate neutrality. Agora Energiewende develops robust policy proposals for decarbonising the economy.	• 12 insights on hydrogen • How to make renewable hydrogen cost-competitive
	Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)	One of FAU's research focuses lies on energy systems of the future. In connection with several partners and across faculties, the FAU is doing research regarding hydrogen and innovative processes to establish a holistic energy system.	
	TU Dresden	The Chair of Hydrogen and Nuclear Energy at the Technical University of Dresden teaches and is doing research regarding the production and application of hydrogen in energy technology and the safety of hydrogen technologies.	
	Technical University of Munich (TUM)	Numerous chairs, research groups, and institutes work together to jointly advance research in the area of hydrogen and PtX at TUM. The TUM Network for Hydrogen and PtX coordinates the research efforts regarding hydrogen and PtX at TUM.	• TUM.Hydrogen and PtX

Denmark

Category	Name	Profile	More information
Business organisations	Dansk Industri Energi (DI Energi)	DI Energi is part of Denmark's largest private business organisation, the Confederation of Danish Industry (Dansk Industri). DI Energi represents over 600 companies across the value chain of energy. Among other things, DI Energi's members are engaged in harvesting synergies between energy forms and technologies through Power-to-X.	• Opportunities in Danish-German cooperation on green hydrogen (in Danish)
	Hydrogen Denmark (Brintbranchen)	Brintbranchen is the Danish organisation for hydrogen and PtX in Denmark. It represents the entire Danish hydrogen and PtX value chain and brings together all stakeholders in this field.	• Project: Hydrogen Mobility Europe • Project: HyLaw
	Wind Denmark	Wind Denmark is a sector organisation representing 2,400 members in the Danish wind turbine sector, counting wind turbines, the wind turbine industry, and private individuals. Its members cover the entire value chain, both onshore and offshore.	• The PtX Alliance (see below)
Companies	A.P. Møller – (Mærsk)	A.P. Møller – Mærsk is an integrated container logistics company. In line with its plans to reduce CO_2 emissions, Mærsk plans to power 12 ships with green methanol produced by biogas/biomass or renewable hydrogen by 2025.	
	COWI	COWI is an international consulting group, specialising in engineering, economics, and environmental science. COWI is focused on developing a green hydrogen expertise and project pipeline. One example is the "Green Fuels for Denmark" project.	• Project: H2RES • Project: Green Fuels for Denmark
	Everfuel	Everfuel is a Danish company with the mission of enabling European-wide production, distribution, and refuelling of green hydrogen at competitive prices. Everfuel aims to facilitate the complete hydrogen value chain from production to point of delivery.	• The Everfuel Farm
	Topsoe	Topsoe specialises in carbon reduction technologies for the chemical and refining industries. Topsoe has developed an integrated hydrogen process H2bridge, specifically tailored for the renewable's hydrocarbon feedstock markets.	• Hydrogen at Topsoe

	Ørsted	Ørsted is a renewable energy company which envisions a world that runs entirely on green energy. Ørsted has ambitious plans to accelerate deployment of renewable hydrogen production and Power-to-X. They are part of many projects regarding green hydrogen production like “Green fuels for Denmark”, “Westküste 100” and “Gigastack”.	• Renewable hydrogen at Ørsted
	Rambøll	Rambøll is a leading engineering, architecture, and consultancy company founded 1945 in Denmark. Rambøll accompanies many projects regarding the pressing topic of green hydrogen and Power-to-X technologies. One of them is the “Bornholm Bunker Hub”, which explores the possibilities for using the Danish island Bornholm as a ‘green gas station’.	• Project: Bornholm Bunker Hub
	Vestas	Vesta’s work revolves around the development and deployment of sustainable energy solutions. They design, manufacture, install, develop, and service wind energy and hybrid projects all over the world.	
Networks, alliances, others	Danish PtX Alliance	The Danish PtX Alliance is a strategic collaboration between Brintbranchen and Wind Denmark and aims to ensure that large scale hydrogen production can be realised. It wants to break down regulatory barriers and therefore contribute to the deployment of PtX in Denmark.	
	German-Danish Hydrogen Network	The German-Danish Hydrogen Network is an initiative for transparency and cross-border cooperation between Germany and Denmark by the German-Danish Chamber of Commerce. It is designed to make players visible and thereby foster contacts between companies and thereby cooperation.	
	Green Hydrogen Hub Denmark (GHH)	GHH aims to establish one of the world’s largest green hydrogen production plants and combine it with an underground hydrogen storage in the area between Hobro and Viborg.	

Public entities	Danish Energy Agency (DEA)	The DEA is responsible for tasks linked to energy production, supply, and consumption, as well as Danish efforts to reduce carbon emissions. It is an agency under the Danish Ministry of Climate, Energy & Utilities.	• Report: Export Potential CCUS & PtX Technology
	Energinet	Energinet is an independent public enterprise owned by the Danish Ministry of Climate, Energy & Utilities. Its core business involves designing, maintaining, and developing the Danish energy system for electricity and gas with a focus on finding cost-effective ways to integrate higher shares of renewables into the system while maintaining a high level of security of supply.	• Energy Islands in Denmark
Universities, think tanks	Aalborg University (AAU)	The AAU Faculty of Engineering and Science with their Energy department is dedicated to research, innovation, and education within the broad field of energy. The Sustainable Fuel Mission focuses on the production of green, renewable, and carbon footprint reduced fuels.	• AAU Energy • Sustainable Fuel Mission • Electrification, Storage, and Integrated Energy Systems
	Hydrogen Valley	The project organisation Hydrogen Valley takes the initiative for activities, business models, and projects that uncover how PtX can promote the green transition of the Danish energy system.	• Project overview
	Technical University of Denmark (DTU)	The DTU Department of Energy Conversion and Storage carries out research regarding electrolysis, hydrogen and PtX. DTU is part of several hydrogen and PtX projects like GreenHy Scale and Greenlab Skive.	• DTU Energy Department

6. Project examples

Germany

Project	Details	Planned capacity	Consortium
AquaVentus	Electrolysis plants in the North Sea (Helgoland)	10 GW by 2035	RWE, Island of Helgoland, Reuther, Vattenfall, Shell, Gasunie, Siemens, Parkwind, MHI Vestas
Hamburg Green Hydrogen Alliance	Production side; several large industrial consumers of hydrogen		Airbus, HHLA, HPA and others
Hamburg Green Hydrogen Hub	Large-scale project to decarbonise an entire port economy	100 MW	Shell, Mitsubishi Heavy Industries, Wärme Hamburg, Vattenfall
Clean Hydrogen Coastline	Electrolysis plants in Northern Germany	400 MW by 2026	Arcelor Mittal Bremen, EWE, FAUN, Gasunie, swb, Tennet
HH-WIN	Hydrogen pipeline network of the Elbe	n.a.	Gasnetz Hamburg, Hamburg Authority for the Environment, Climate, Energy and Agriculture
HyPerLink	Project by Gasunie: Hydrogen pipeline network in Northern Germany (length of approx. 610 km)	Network capacity up to 7.2 GW	n.a.
HySCALE100	Hydrogen production for the decarbonisation of petrochemicals and cement	100 MW	Hynamics, Holcim Deutschland, Ørsted, Raffinerie Heide GmbH
H2Stahl	One of the "Reallabore der Energiewende": plans to use hydrogen in steel production	n.a.	thyssenkrupp, AirLiquide Deutschland
REFHYNE	Electrolysis plant at Rheinland refinery in Cologne	10 MW	Shell, ITM Power, SINTEF, Sphera, Element Energy

The Federal Ministry for Economic Affairs and Climate Action has released a One-Stop-Shop Hydrogen where additional information and further projects can be found (in German). The BMWK has also released a map showing all IPCEI Hydrogen projects in Germany.

Denmark

Project	Details	Planned capacity	Consortium
Bornholm Bunker Hub	Energy Island at Bornholm that aims to establish infrastructure for fuel storage and bunkering	3 GW offshore wind power	Ørsted, Bornholmslinjen, Topsoe, Bunker Holding Group, Wärtsilä, Rambøll, Bureau Veritas, Port of Roenne A/S, since August 2022 in partnership with Germany
Vindø	Energy Island in the west of Jutland	3 GW offshore wind power (10 GW in the long term)	PensionDanmark, PFA, Andel
H2 Energy	Construction of two PtX plants in Esbjerg to produce green hydrogen	1 GW	H2 Energy Europe
Green Fuels for Denmark	Electrolysis plant in Greater Copenhagen area to produce sustainable fuels for the transport sectors	10 MW in 2023, 100 MW in 2025, 250 MW in 2027, 1.3 GW in 2030	Ørsted, Copenhagen Airport, A.P. Møller-Mærsk, DSV Panalpina A/S, DFDS, SAS, COWI
Green Hydrogen Hub Denmark	Electrolysis and hydrogen storage facility in Hobro/Viborg	Up to 1 GW (long term)	Eurowind, Energinet, Corre Energy
Høst	Electrolysis plant by the Port of Esbjerg for ammonia production for agriculture and shipping	1 GW	CIP, Din Forsyning, Esbjerg Havn, Arla, Danish Crown, Mærsk, DFDS
HySynergy	Large-scale production and storage facility of green hydrogen	20 MW (1 GW in 2030)	Everfuel, Crossbridge Energy, Aktive Energi Anlæg, Trefor Elnet, Energinet, TVIS, EWII
Green HyScale	Electrolysis plant in Skive, project is funded by the EU (Horizon 2020)	100 MW	GreenLab A/S, Green Hydrogen Systems A/S, Energy Cluster Denmark, Lhyfe, Siemens Gamesa, Equinor Energy A/S, DTU, Imperial College London, Quantafuel and Euroquality

A map by Hydrogen Denmark gives a broader overview of PtX projects in Denmark.

7. Key messages

Both (Northern) Germany and Denmark have realised the potential of green hydrogen and PtX technologies and released extensive strategies regarding the topic. **Green hydrogen and e-fuels will be a main solution for the sectors hard to electrify from 2030 and onwards**.

In line with its European Green Deal, the EU has also released a hydrogen strategy with the goal to reach 40 GW electrolysis capacity by 2030. **As the EU has defined green hydrogen as a key priority, Germany and Denmark enjoy good framework conditions that define the implementation of their national strategies**.

Cross-border cooperation between Germany and Denmark is not only possible but essential in mastering the task to reduce greenhouse gas emissions and transform the energy sector. With cooperation between Germany and Denmark, the region has the potential to become a world leader in the development and production of green hydrogen.

By collaborating, the countries can reap the benefits of having an appropriate demand and supply ratio of renewable energies and being neighbouring countries.

A **German-Danish hydrogen cooperation** essentially holds **three key opportunities**:

1. **Establishing a hydrogen network**: The repurposing of existing gas pipelines between Esbjerg and Heidenau (complemented by newly constructed pipeline parts and compressors) holds an H2 transport capacity of up to 8.6 GW/h.[XIII]
2. **Hydrogen infrastructure for heavy-duty vehicles**: 5,000 trucks cross the border between Germany and Denmark every day. This route can be used as a hydrogen infrastructure for heavy-duty vehicles.
3. **Ports and shipping**: Shared visions between the Port of Hamburg and Danish ports regarding green shipping hold the opportunity to use hydrogen (in the form of methanol or ammonia) to sustainably fuel ships.

9. Recent developements

Realizing the opportunities for cross-border cooperation, Germany and Denmark have recently taken the first steps towards a shared hydrogen infrastructure. Together with Belgium and the Netherlands, the countries signed the Esbjerg declaration in May of 2022, which calls for a greatly expanded offshore energy production in the North Sea. This is coupled with the combined target of about **20 GW green hydrogen production capacity by 2030**.

Additionally, in August of 2022 Denmark's and Germany's Ministers for Foreign Affairs signed a common plan of action regarding several topics, one of them being energy policy. The agreement recognizes the potential that Danish hydrogen production holds for the German industry and aims to establish the **framework for cross-border trade of green hydrogen**. It specifically mentions the establishment of **hydrogen pipelines** between the two countries and the **decarbonization of commercial shipping using green hydrogen**.

Another developement also came in August 2022 in the form of an agreement regarding the developement of the "Energy Island Bornholm" project, which was signed by the Danish Minister of Climate and Energy and Public Utilities as well as the German Minister of Economy and Climate. In conjunction with a **planned expansion of 1 GW** additional offshore energy capacity, a 470 kilometre long cable will **connect the German and Danish grid** via a substation on Bornholm. Costs and benefits of the project will be shared equally between Denmark and Germany. The energy island and associated Power-to-X facilities will be able to **supply 4.5 million Danish and German households with green electricity and is expected to be completed in 2030**.

During the Baltic Energy Security Summit in Copenhagen on the 30th of August, representatives of the **eight EU countries bordering the Baltic Sea signed a joint declaration of energy ministers on strengthening energy security** in the Baltic Sea region through the development of renewable energies. **Green hydrogen produced from electricity generated by offshore wind power will play an important role in transitioning away from Russian fossil fuels** for these countries.

9. Endnotes

[I] Based on: Jeppe Grue (COWI): Experience from Denmark global leaders in Power-to-x projects (IMECHE Webinar, 19.01.2022), online: https://www.youtube.com/watch?v=NlaGHHfI7g8.

[II] Brändle, Georg/Schönfisch, Max/Schulte, Simon (Institute of Energy Economics at the University of Cologne): Estimating Long-Term Global Supply Costs for Low-Carbon Hydrogen, ISSN: 1862-3808.

[III] Brändle, Georg/Schönfisch, Max/Schulte, Simon (Institute of Energy Economics at the University of Cologne): Estimating Long-Term Global Supply Costs for Low-Carbon Hydrogen, pp. 14 ff.

[IV] Danish Ministry of Climate, Energy and Utilities: The Government's strategy for POWER-TO-X 2021, p. 5.

[V] Danish Ministry of Climate, Energy and Utilities: The Government's strategy for POWER-TO-X 2021, p. 5.

[VI] Danish Ministry of Climate, Energy and Utilities: The Government's strategy for POWER-TO-X 2021, p. 5.

[VII] BMWK: https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/12/20211223-900-millionen-euro-fuer-wasserstoffprojekt-h2global.html.

[VIII] BMWK: https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210528-bmwi-und-bmvi-bringen-wasserstoff-grossprojekte-auf-den-weg.html.

[IX] BMWK: https://www.bmwi.de/Redaktion/DE/Dossier/energieforschung-und-innovation.html.

[X] Gasunie/Energinet: Pre-feasibility Study for a Danish-German Hydrogen Network, April 2021, p. 4.

[XI] Gasunie/Energinet: Pre-feasibility Study for a Danish-German Hydrogen Network, April 2021.

[XII] Prognos, Öko-Institut, Wuppertal-Institut (2020): Klimaneutrales Deutschland. Studie im Auftrag von Agora Energiewende, Agora Verkehrswende und Stiftung Klimaneutralität.

[XIII] Gasunie/Energinet: Pre-feasibility Study for a Danish-German Hydrogen Network, April 2021, pp. 27 f.

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