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Executive Summary

⊕ Hydrogen may be the smallest element but it is the crucial one to achieve our climate action goals. The right conditions and clear, ambitious targets are needed to switch to a hydrogen economy successfully. If this is successful, North-West Europe could become the focal point for global development due to its conditions that are unique worldwide.



With the hydrogen roadmap presented here, North Rhine-Westphalia shows that achieving the Paris climate action targets and strengthening the economic and industrial location can go hand in hand. A quarter of the current CO₂ emissions in North Rhine-Westphalia can be saved by hydrogen alone.

Numerous studies show that hydrogen plays a key part in an economically cost-efficient and climate-neutral energy system. Depending on the scenario, the bandwidths range from 250 to 800 terawatt hours (TWh) of hydrogen demand per year in Germany. Hydrogen is essential for many processes in energy-intensive industry. Hydrogen is also expected to be needed in the mobility sector, for example in buses or trucks, and in the energy sector, for example in gas turbines. Large quantities of hydrogen are primarily required for our energy-intensive industry. These quantities need to be provided reliably and at globally competitive prices to make North Rhine-Westphalia a viable industrial and business location for the future.

However, we do not only want to use hydrogen to reduce CO₂ emissions but also to use the economic opportunities associated with hydrogen to maintain and expand sustainable jobs and create value in North Rhine-Westphalia. The opportunities arise from the wide range of hydrogen-related technologies that need to be developed and produced. These are not only electrolyzers and fuel cells but also hydrogen-compatible pressure tanks, compressors, gas turbines, pipelines, valves, sensors, etc. This could result in new markets and export opportunities for North Rhine-Westphalia. Eventually, securing our energy-intensive industry will also depend on the development of a hydrogen economy.

Requirements to establish a hydrogen economy

1. International markets for hydrogen and power-to-liquids

Analyses carried out by Forschungszentrum Jülich (FZJ) for this roadmap show that a secure and cost-efficient energy supply in Germany and North Rhine-Westphalia can only be achieved in the medium and long term with considerable import volumes.

For Germany, the demand for hydrogen and liquid fuels and raw materials (power-to-liquids) will add up to almost 900 TWh per year by 2050 (Figure 1). About 75 percent of this demand will probably be covered by imports.

North Rhine-Westphalia has an even higher import quota of almost 90 percent here, which makes it clear that we cannot cover our energy and raw material requirements for a climate-neutral economy with the local renewable capacities alone. North Rhine-Westphalia is and remains an energy importing state. According to FZJ calculations, North Rhine-Westphalia's hydrogen demand amounts to a total of 104 TWh per year, of which roughly 18 TWh are

generated locally (Figure 2). The majority of North Rhine-Westphalia's demand, at around 42 TWh per year, comes from the industrial sector. Mobility and the electricity generation also play an important role at 33 and 26 TWh per year respectively.

Due to this gap in coverage, we intend to focus specifically on building international partnerships in the next few years in order to be able to meet the growing demand for hydrogen. Possible export countries are the European North Sea states, the existing export countries for fossil fuels or new regions such as North Africa. But across the board, the development of a European market at least for internationally tradable, climate-neutral raw materials will also become very important in order to be able to cover the demand in Europe. North Rhine-Westphalia will support this federal government and European Union (EU) development task, just as we already play a crucial role as a consumer and distribution hub, for example for natural gas.

Figure 1: Hydrogen and power-to-liquid supply in Germany in TWh per year in 2050

data based on the accompanying study by FZJ

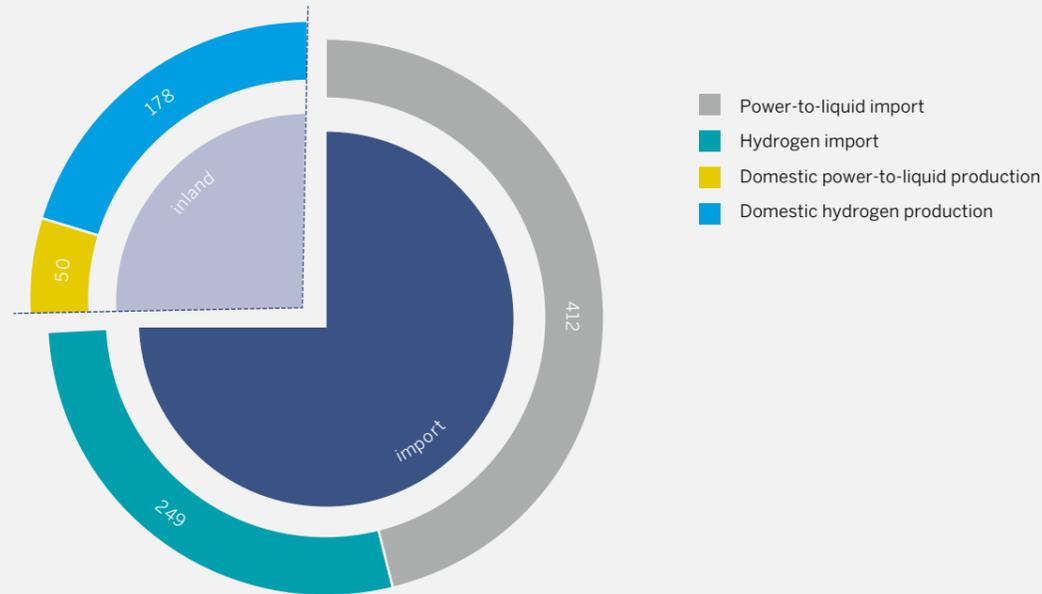
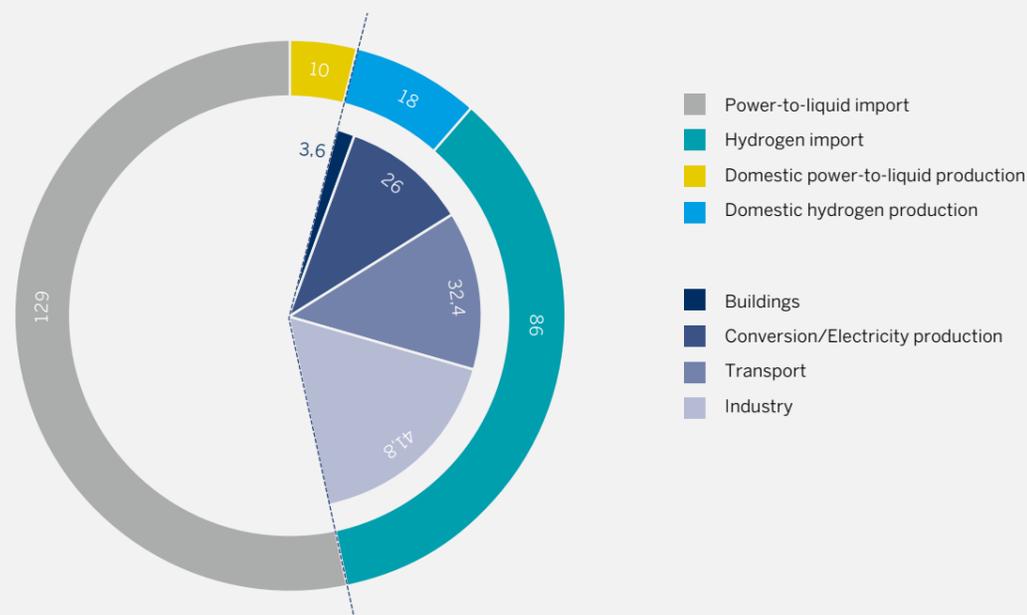


Figure 2: Hydrogen and power-to-liquid supply in North Rhine-Westphalia in TWh per year in 2050

data based on the accompanying study by FZJ



2. Establishing the hydrogen infrastructure quickly and cost-effectively

The energy transition needs new infrastructures. The rapid establishment of hydrogen transport networks is crucially important in this context and must be included in the Energy Industry Act regulation by the Federal Government as quickly as possible adopting a technology-neutral approach. The adaptation of the legal framework should be initiated in the short term and before the end of this legislative period. We expressly support the green gas scenario in the Gas 2030 network development plan and therefore the establishment of a hydrogen network of around 1,300 kilometres by 2030. The analyses conducted by FZJ have clearly emphasised that the conversion or continued use of existing infrastructures makes a crucial contribution to a cost-efficient and, above all, timely transformation.

North Rhine-Westphalia is already working on the market ramp-up of hydrogen technologies and will intensify its activities

North Rhine-Westphalia is already working intensively to create the conditions for the establishment of a hydrogen economy and will intensify its activities, particularly in the fields of action listed below. We have set specific targets for each sector and intend to work with all stakeholders to achieve these targets.

North Rhine-Westphalia's 2025 targets:

- ⦿ Industry
 - First industrial-scale direct-reduced-iron plant for the production of hydrogen-based steel at the Duisburg site
 - Power-to-liquid demonstration plant for the production of synthetic fuels and raw materials with a capacity of several 100 tonnes per day
 - First large-scale industrial plants for climate-neutral ammonia and methanol synthesis
 - Test and pilot plant for the pyrolytic production of hydrogen

- ⦿ Mobility
 - More than 400 fuel cell trucks
 - At least 20 truck filling stations
 - 60 car filling stations
 - 500 hydrogen buses for public transport
 - The first hydrogen-powered barges
- ⦿ Energy & infrastructure
 - Almost 500 kilometres of hydrogen pipeline in Germany, 120 kilometres of which are in North Rhine-Westphalia
 - North Rhine-Westphalia connected to the first supra-regional hydrogen lines
 - More than 100 megawatt electrolysis plants for industrial hydrogen production
 - Natural gas-based electricity and heat generators increasingly developing towards hydrogen compatibility
 - Implementation of the hydrogen projects in the rhenish mining district

North Rhine-Westphalia's 2030 targets:

- ⦿ Industry:
 - Pilot plant for the complete substitution of natural gas by hydrogen for heat generation in glass production
 - Integrated use of synthetic fuels and CCU in the tile and brick industry in an industrial scale plant
 - Demonstration project for a hydrogen-fired rotary kiln in foundry technology
 - Development and evaluation of processes to integrate hydrogen in cement industry
 - Implementation of the projects from the „Aufbruch in die Zukunft“ initiative by unternehmer nrw
 - Expansion of hydrogen-based steel production
- ⦿ Mobility:
 - 11,000 fuel cell trucks over 20 tonnes
 - 200 filling stations for trucks and cars
 - 1,000 fuel cell waste bins
 - 3,800 fuel cell buses for public transport
- ⦿ Energy & infrastructure
 - 1,300 kilometres of hydrogen pipelines in Germany, 240 kilometres of which are in North Rhine-Westphalia
 - First investments in electricity and heat generation plants based on hydrogen
 - 1 to 3 gigawatts of electrolysis capacity in North Rhine-Westphalia



Our most important fields of action towards a hydrogen economy

→ Expanding and intensifying international partnerships:

We aim to join the European Alliance for Clean Hydrogen. In addition to existing cooperation projects with the Netherlands, we will enter into further collaborations to reliably increase the availability of hydrogen in North Rhine-Westphalia. In addition, together with European partner countries, we are working with consortia of companies to attract investment to North Rhine-Westphalia, for example within the framework of the Important Project of Common European Interest (IPCEI).

→ Strengthening research and innovation:

North Rhine-Westphalia's research landscape is already characterised by a large number of high-performance institutes focusing on different hydrogen technologies. We want to push development further with the new Helmholtz cluster for a sustainable and infrastructure-compatible hydrogen economy, the first industrial-scale Liquid Organic Hydrogen Carrier (LOHC) test field or, for example, the establishment of hydrogen start-ups. We will also support the existing research institutions in opening up further fields of research.

→ Exploiting the potential in mechanical and plant engineering:

North Rhine-Westphalia is home to a wide variety of component and system manufacturers in the field of hydrogen technologies. High-quality products are already being manufactured in North Rhine-Westphalia from fuel cell systems and electrolyzers to pressure tanks, gas turbines, sensors and many more. We want to strengthen sustainable value creation in North Rhine-Westphalia by implementing the hydrogen district projects in the Rhenish mining district, setting up an operational research centre for industrial electrolysis technologies in the Ruhr area and many other corporate activities in the field of hydrogen technology.

In addition, we also demand that the German government and the EU Commission:

→ Make hydrogen projects ready for investment:

Incentive programmes such as Carbon Contracts for Difference (CCfD) for industrial applications and the adaptation of the taxes and levies system must be implemented before the end of this legislative period.

→ Ambitiously implement the Renewable Energies Directive (RED II):

Rapid implementation in national law may be an important step towards scaling up electrolysis technology.

→ Guarantee a technology-neutral approach:

Grey, blue and turquoise hydrogen are necessary transitional solutions for a fast and cost-efficient market ramp-up. We must be able to make use of all the available options, especially in the market ramp-up phase.

→ Enable energy-intensive industry to be transformed:

A climate-neutral industry by 2050 is only possible through an innovation-friendly investment framework and an import structure that is as broadly diversified as possible and enables supply at internationally competitive prices.

→ Develop European standards:

There is a need for certification and guarantees of origin systems defined at least at European level for the international trade in hydrogen and power-to-liquids.

→ Design gas-based supply security H₂-ready:

The further development of the hydrogen compatibility of plants, such as gas turbines or CHP plants, and their components in terms of H₂ readiness must be supported as early as possible.

→ Support further development of natural gas storage facilities into hydrogen storage:

As a result of the further development towards hydrogen storage, natural gas storage capacities are available in Germany to continue to play a crucial role in the safe and flexible supply of gas. North Rhine-Westphalia has very good conditions with regard to existing and potential storage locations. Moreover, storage facilities will have an additional role to play in future in bridging slack periods and integrating renewable energies.

→ Consider the energy infrastructure across systems:

Future integrated infrastructure planning for electricity, natural gas and hydrogen must ensure that electrolyzers, for example, can be integrated into the existing energy infrastructure in a way that is beneficial to the network and system.

→ Continue and further develop the Hydrogen and Fuel Cell Technology national innovation programme:

The transport sector in particular should be supported further by long-term support frameworks for the market ramp-up. Continuous and resourceful support is needed for the market ramp-up.

We will make representations to the EU Commission and the German Federal Government for the rapid development of suitable framework conditions that will contribute to the success of an internationally connected hydrogen economy, as we are convinced that North Rhine-Westphalia can be part of a concentrated, strongly networked and unique hydrogen technology landscape in North-West Europe.



North-West Europe has exceptional conditions to become a focal point for a European hydrogen economy

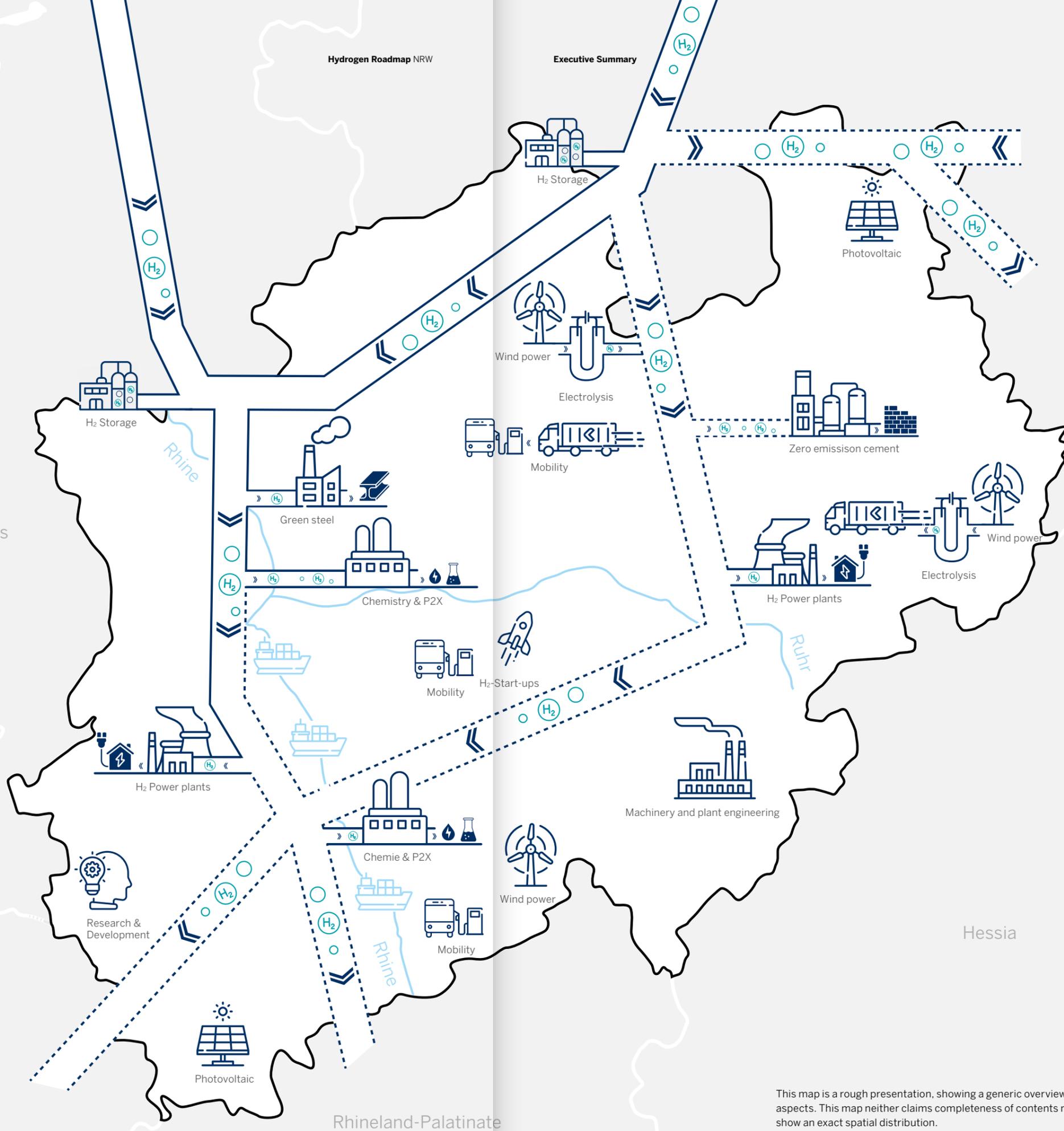
North-West Europe is characterised by a very well developed and internationally connected energy infrastructure network with numerous entry points for imported energy sources (for example, via ports). This alone is already a very important starting point for its further development into a significant focal point for a European hydrogen economy.

Another positive aspect is that the conversion from L-gas to H-gas, which mainly affects the Netherlands, Lower Saxony and North Rhine-Westphalia, will free up natural gas pipelines that can be used for hydrogen transport. These pipelines can connect the future (industrial) high-demand areas, for example in the Rhine-Ruhr region, in Lingen (or Chemelot) to the generation centres in the north. With the offshore wind energy sites in the European North Sea, but also good onshore wind energy sites in Northern Germany and the Netherlands, future electrolysis sites can be connected to the high-demand areas further south. Another unique selling point for the North-West Europe region is the existence of huge energy storage capacity in the form of salt caverns. These can be filled with hydrogen in future and therefore contribute equally to the integration of renewable energies and to the security of supply, just like in the past. The interaction of these five factors

- ✔ an internationally well connected energy infrastructure network,
- ✔ gas pipelines that become available as part of the L-gas to H-gas conversion,
- ✔ the North Sea as an excellent wind energy location,
- ✔ the existence of large salt cavern storage facilities and
- ✔ a high demand for hydrogen due to density of industrial activity

in geographically close proximity has exceptional potential for the development of a European and global hydrogen economy.

Our goal is for North Rhine-Westphalia to be part of a concentrated, strongly networked and unique hydrogen technology landscape in North-West Europe. We would now like to take advantage of the opportunities that the use of hydrogen has to offer in the individual sectors and make the industrial location of North Rhine-Westphalia fit for the future. We will do everything in our power to achieve this goal and want to pursue this path together and in cooperation with all society's stakeholders.



The Netherlands

Lower Saxony

Hessia

Belgium

Rhineland-Palatinate

This map is a rough presentation, showing a generic overview of single aspects. This map neither claims completeness of contents nor does it show an exact spatial distribution.