SECTOR COUPLING – THE PATH TO A SUCCESSFUL ENERGY TRANSITION

A project by Amprion and Open Grid Europe

hybridge

CONTENTS

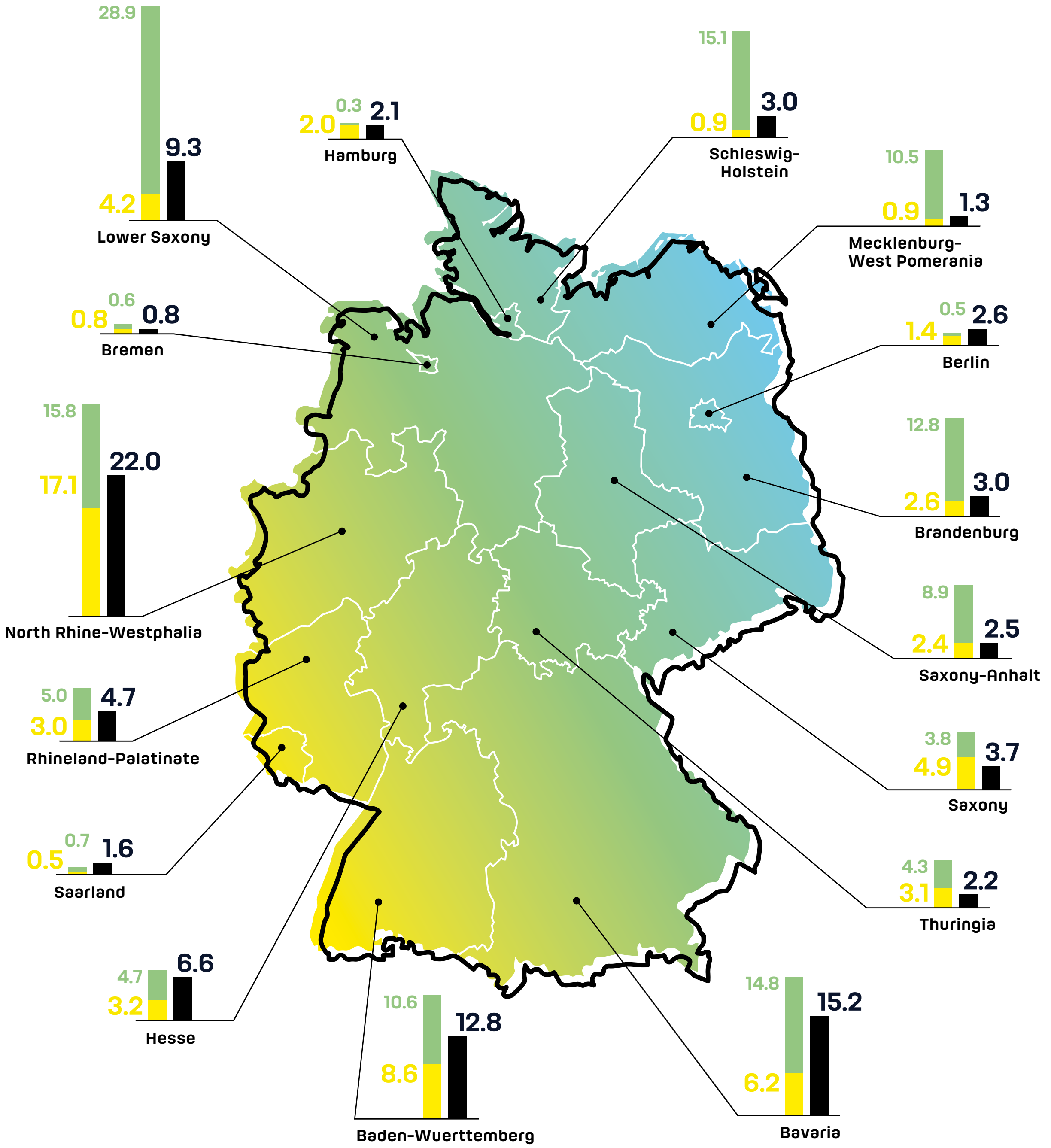
hybridge – this is the name of the large-scale power-to-gas project by Amprion and Open Grid Europe (OGE). Our plan is for our pilot plant to be able to convert up to 100 megawatts of electrical power into hydrogen by 2023. With this project, we want to further develop a technology that will play a key role in the transformation of our energy system.

The energy world of the future

From large wind farms in the North and Baltic Seas to photovoltaic plants in Southern Germany – the way electricity is generated is changing rapidly. Not only in Germany but throughout Europe. The European Union has set itself the target of reducing greenhouse gas emissions by 40 per cent by 2030. This is why the share of renewable energy sources in Germany's energy demand must rise to 65 per cent. For comparative purposes: In 2017, around 36 per cent of Germany's power demand were covered by renewable energy sources. This development poses major challenges to our power system. Renewable energy sources are not controllable and behave differently from conventional power plants, which have provided most of the electricity required until now.

The electricity production of wind energy and photovoltaic plants depends on external conditions. Transmission system operators estimate that in 2030 wind energy and photovoltaic plants will provide up to 133 gigawatts of power throughout Germany on windy and sunny days. However, the predicted load peaks at 92 gigawatts and is considerably lower in most hours of the year. Consequently, the number of times when the supply of renewable energy clearly exceeds demand will rise. But conversely, there are also times when weather conditions are unfavourable. Then wind energy and photovoltaic plants barely feed any power into the grid. During these "dark doldrums", the supply of power from other sources must be ensured. This is a challenge, because with the expansion of renewable energy sources and the phasing out of nuclear power and coal, more and more conventional power plants are being shut down.

The transmission system must hold this "changing energy landscape" together. Already in 2018, wind energy and photovoltaic plants together fed up to 50 gigawatts into the grid. They supply green electricity, primarily in sunny and windy regions, which often has to be transported over long distances to consumption centres. As a result of this new power generation landscape, the average distance to the consumer has quadrupled and is now around 240 kilometres. As the German transmission system was not originally designed to meet these requirements, it needs to be upgraded and expanded at numerous points. The necessary projects are described in the Network Development Plan. These measures alone are not sufficient in the long term and our energy system reaches its limits. Then, more and more often supply clearly exceeds demand – and vice versa. In order to nonetheless be able to make full use of the amount of supply-dependent electricity available, the energy system of the future must be supplemented by seasonal storage facilities and innovative concepts such as sector coupling.

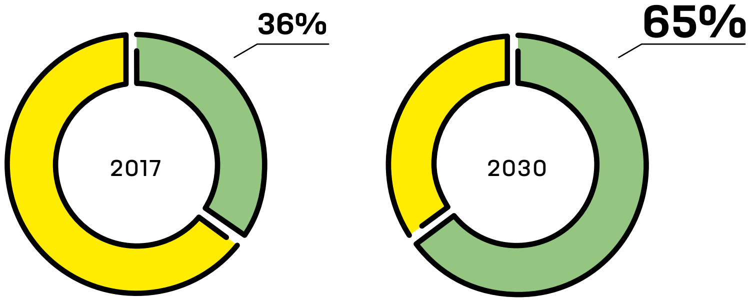


ELECTRICITY LANDSCAPE 2030

- Maximum available capacity from conventional power plants in gigawatts
- Maximum available capacity from renewables in gigawatts
- Maximum load in gigawatts

Source: In-house calculations based on the Network Development Plan 2030 (2019), scenario B

SHARE OF RENEWABLE ENERGY SOURCES IN ENERGY DEMAND



Source: Federal Ministry for Economic Affairs and Energy

Sector coupling at system level

What to do with the ever increasing quantities of electricity from wind and solar that do not always find takers? This key question needs to be answered in order to initiate the next stage of the energy transition. A key approach to solving this issue is to divert this electricity to other sectors – where large amounts of energy are also required. This is technically possible by coupling the existing infrastructures of the German electricity and gas system with each other. Power-to-gas systems act as a bridge between the individual systems. They enable electricity to be transformed into hydrogen – an important raw material and environmentally friendly energy source that can be used in all sectors. The same applies to synthetic methane, which in turn can be obtained from hydrogen.

Until now, the transformation and transport of energy has always taken place within each system separately. For example, electricity transport: Power plants feed electricity into the grid. This electricity is then transmitted via transmission lines, passed on to other voltage levels via current transformers and transported on from there to the end customers. Gas transport works in a similar way – from the transport network via the regional network to the distribution network. The power-to-gas approach opens up the option of transporting energy between sectors as well. Here, electricity is converted into hydrogen in the power-to-gas system (the "sector transformer"), fed into the gas system and transported on to the respective point of consumption.

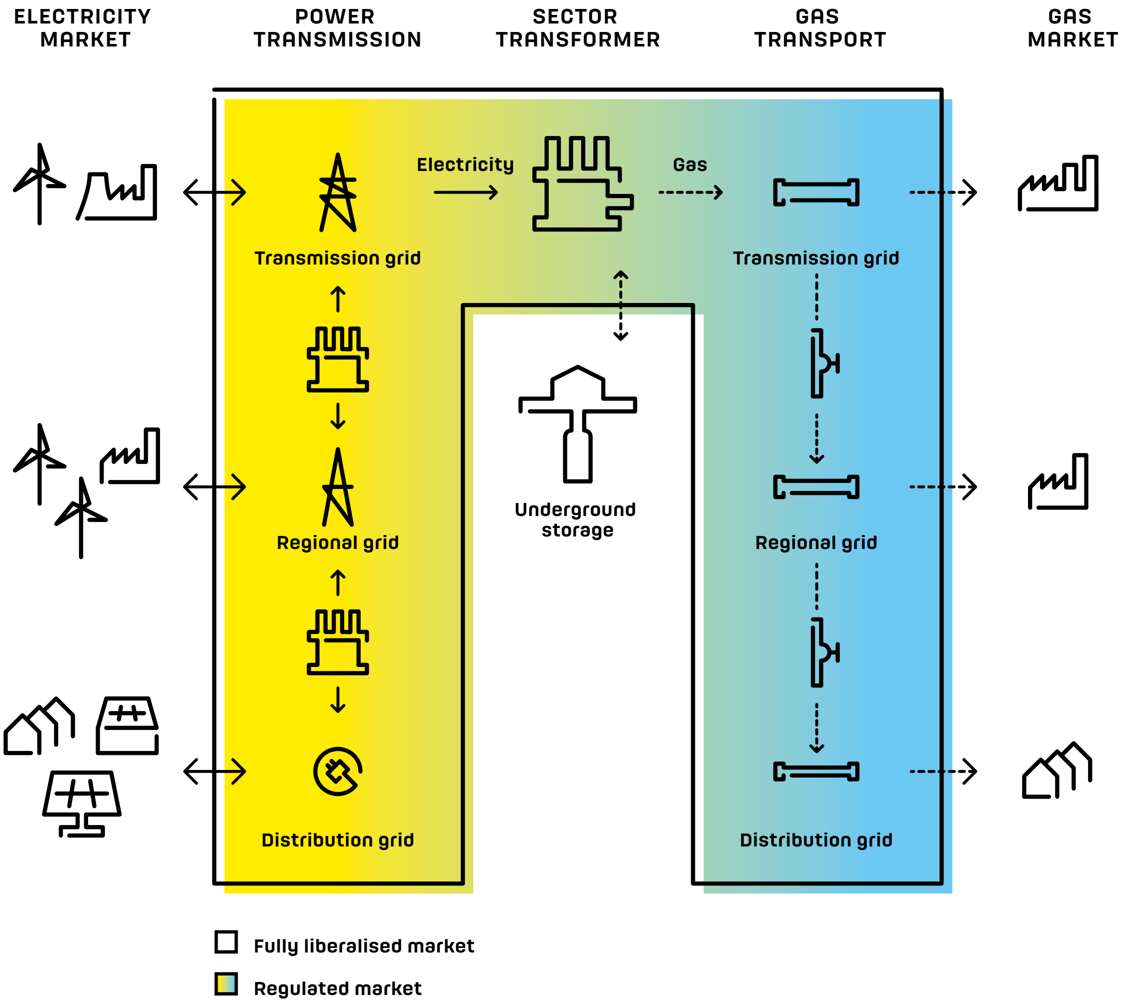
These three criteria are crucial for sector coupling to achieve maximum economic benefits and maximum sustainability:

- **SIZE:** The power-to-gas plants must be integrated into the electricity and gas system in a suitable dimension and at the highest level. This is the only way to harness the capacities of the transportation networks for electricity and gas and the gas storage facilities connected to them.

- **LOCATION:** The systems must be installed at suitable contact points between the electricity and gas transportation networks. Only in this way, technically feasible and economically efficient transitions can be created between the electricity and gas systems.

- **TIMING:** It must be possible to coordinate the operation of the systems in such a way that the actual feed-in of renewable energy, the electrical load, the current flows in the electrical system, the volume flows of gas transport and the filling levels of the gas storage facilities are always seen as an integrated system. In this way, renewables can be integrated into the energy system in a way that is beneficial to the system as a whole. At the same time, the demand profile of a hydrogen application can be uncoupled from the supply profile of renewables.

COUPLING POWER AND GAS SYSTEMS – AN OVERVIEW



Basic principle

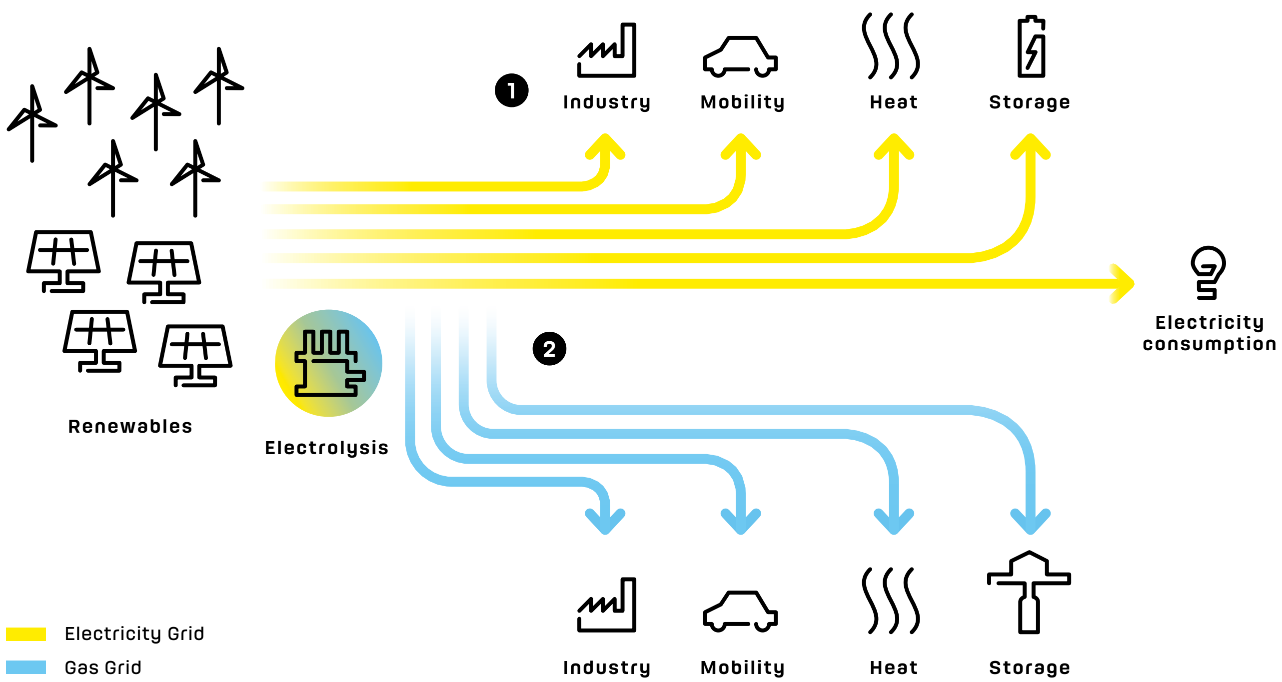
How can we effectively integrate the strongly fluctuating output of wind energy and photovoltaic plants into our energy system? With the help of sector coupling at system level, the following basic principle can be implemented:

1. If there is corresponding demand for electricity and if electricity transport is technically possible, the electricity generated from renewable energy sources will be transported via the electricity grid and used directly.

2. If the electricity networks are fully utilised or consumers demand less electricity than is available, the electrical energy will be transformed using power-to-gas plants, transported in the form of gas and used in other sectors. This enables the growth of renewable energy to be decoupled from the expansion of electricity grids in future.

3. If need be, in the event of supply bottlenecks, gas could be converted back into electricity in power plants on the market. However, this is unlikely to be the case for decades.

REROUTING ELECTRICITY TO THE GAS SECTOR



Model for the future

Many factors must be taken into account for power-to-gas plants to combine the gas and electricity systems expediently in future. Operation depends on the actual feed-in of renewable energy sources, the electrical load, the current flows in the electrical system, the gas flows in the transmission system and the filling levels of gas storage tanks. Amprion and OGE are particularly well positioned to perform this crucial coordination task – because the project partners are already responsible for controlling energy flows via their lines and for operating stable systems.

The energy transported via the gas and electricity lines is never owned by the "forwarders", the network operators. They make their infrastructure available to all market participants on a non-discriminatory basis and are remunerated for their transport services via a regulated network charge. This important feature of the liberalised energy market is called third party access. It can and must continue to be in place when the electricity and gas infrastructures are coupled at system level.

Sector coupling at system level involves transformation between two regulated areas – the electricity transmission network and the gas transmission network. It is planned for the transmission system operators to be responsible for the planning, construction and operation of the sector transformer, i. e. the power-to-gas plant. This will be financed through network charges and means that no state support system, allocation system or similar will be needed for these new network elements.

As the "bridging capacity" between the systems is limited, the network operators plan to auction it off to traders or direct customers. The revenues from the auctions are offset against the costs by the network operators and reduce the network charges. This principle has been applied for years in the electricity system for cross-border interconnectors and cross-border gas transport capacities.

COST-BENEFIT RATIO

The lighthouse project planned by Amprion and OGE aims to transform an electrical input of 100 megawatts into hydrogen and will cost around 150 million euros. This investment is marginal in relation to the economic benefits that sector coupling on an industrial scale can deliver in future. If it is possible to integrate power-to-gas plants into the energy system in a practical way, end customers will benefit considerably from this in the long term.

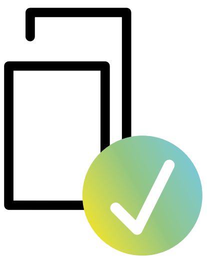
Project

Amprion and OGE are planning the first large-scale power-to-gas-plant in Germany to convert electricity from renewable energy sources into hydrogen. A suitable location for the hybridge pilot project is in southern Emsland: On the border between Lower Saxony and North Rhine-Westphalia, there is an ideal intersection between electricity and gas grids.

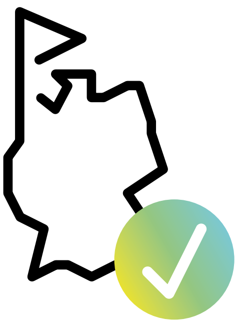
The following is planned: An electrolyser with electrical input of 100 megawatts will be installed near one of Amprion's substations and connected to Amprion's electricity grid. Based on this, we plan to test all future ways of integrating hydrogen into the energy system in the hybridge project: OGE plans to convert parts of its existing gas network for the exclusive transport of pure hydrogen. Companies located near the new hydrogen pipeline can use the green hydrogen. In the further course of the project, the provision of hydrogen filling stations in the mobility sector, for example in motor vehicles or trains, is also possible. In addition, gas storage facilities will be converted as well in future in order to temporally decouple the supply of renewable energy sources from the demand for hydrogen. The storage facilities can then take in hydrogen instead of natural gas and feed it back into the hydrogen network. In this way, a reliable supply of hydrogen based on renewable energy can be efficiently realised.

Adding hydrogen to natural gas networks is another option that will be tested as part of the project. The green gas can then also be used for other purposes such as heating. As part of the OGE network, the hydrogen network will be connected to both the transmission network and to regional, local natural gas networks. OGE ensures that a limited amount of hydrogen can be added to the natural gas in compliance with current regulations. When these options have been exhausted, hydrogen can also be methanised with CO2 and fed into the natural gas grid too.

The technological prerequisites for the construction of the plant are already in place today. If the legal and regulatory authorities consent to the project, Amprion and OGE can begin the approval process and construction in the near future. The plant would then be ready for operation in 2023.

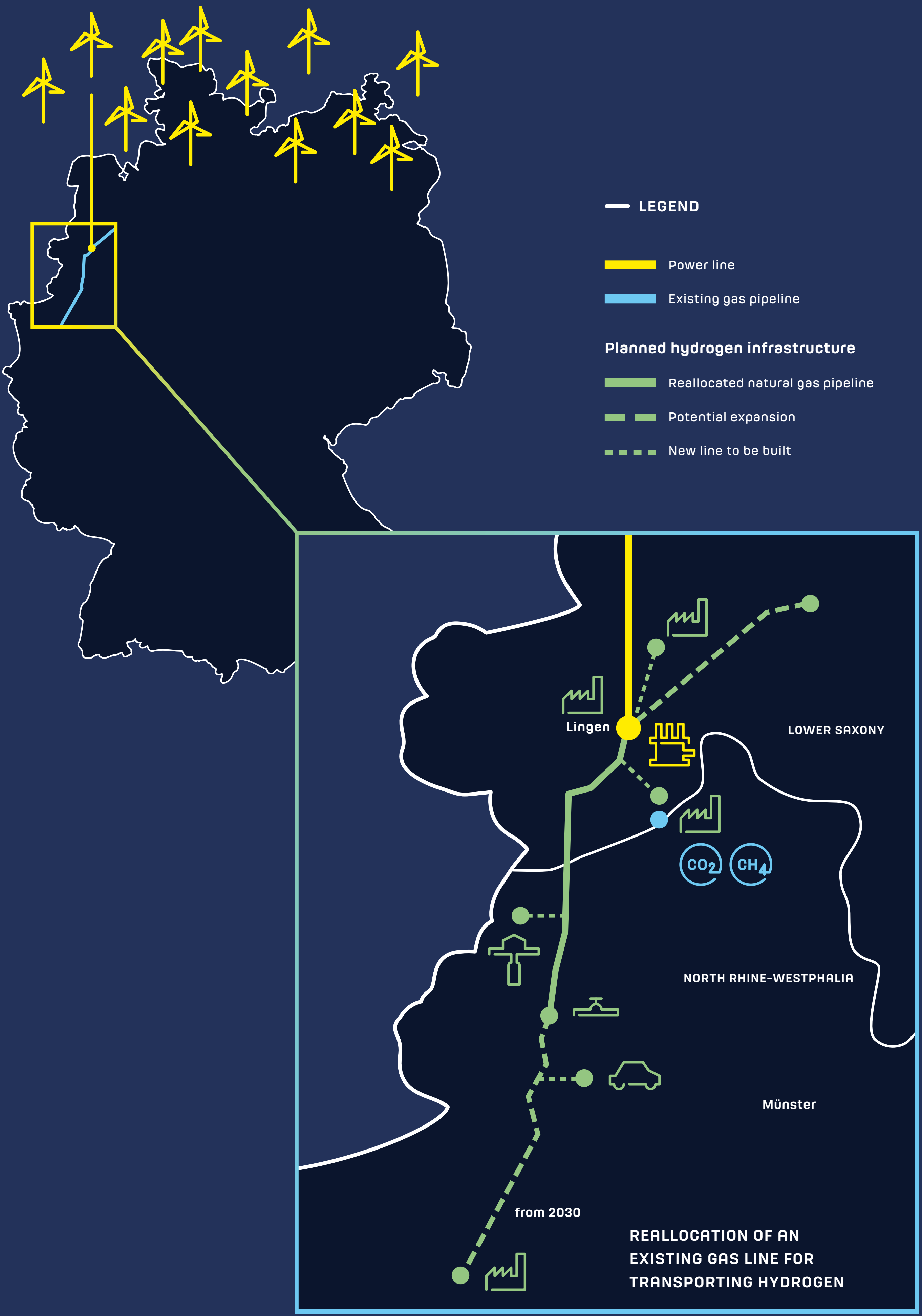


Technical concept



Location

Applications



LEGEND
Power line
Existing gas pipeline
Planned hydrogen infrastructure
Reallocated natural gas pipeline
Potential expansion
New line to be built
Lingen
LOWER SAXONY
CO2
CH4
NORTH RHINE-WESTPHALIA
Münster
from 2030
REALLOCATION OF AN
EXISTING GAS LINE FOR
TRANSPORTING HYDROGEN

Technology

❶ Electrolysis

The operating principle of power-to-gas is based on a chemical process: water electrolysis. Water is split into hydrogen and oxygen using electricity. The hydrogen obtained in this way subsequently contains a large part of the energy input. Since no greenhouse gases are released during electrolysis and subsequent use, hydrogen is considered emission-free ("green hydrogen") if the electricity used comes from renewable energy sources.

Two technologies are currently available for large-scale electrolysis of water: alkaline and proton exchange membrane electrolysis. Amprion and OGE are considering both technologies with their respective advantages and disadvantages for use in the project.

❷ Hydrogen transport

Existing natural gas pipelines can be used to transport the green hydrogen to the location of consumption or storage. This does not just make sense from an economic point of view; experience shows that such a measure is also more socially acceptable, as only minor interventions in the landscape are needed.

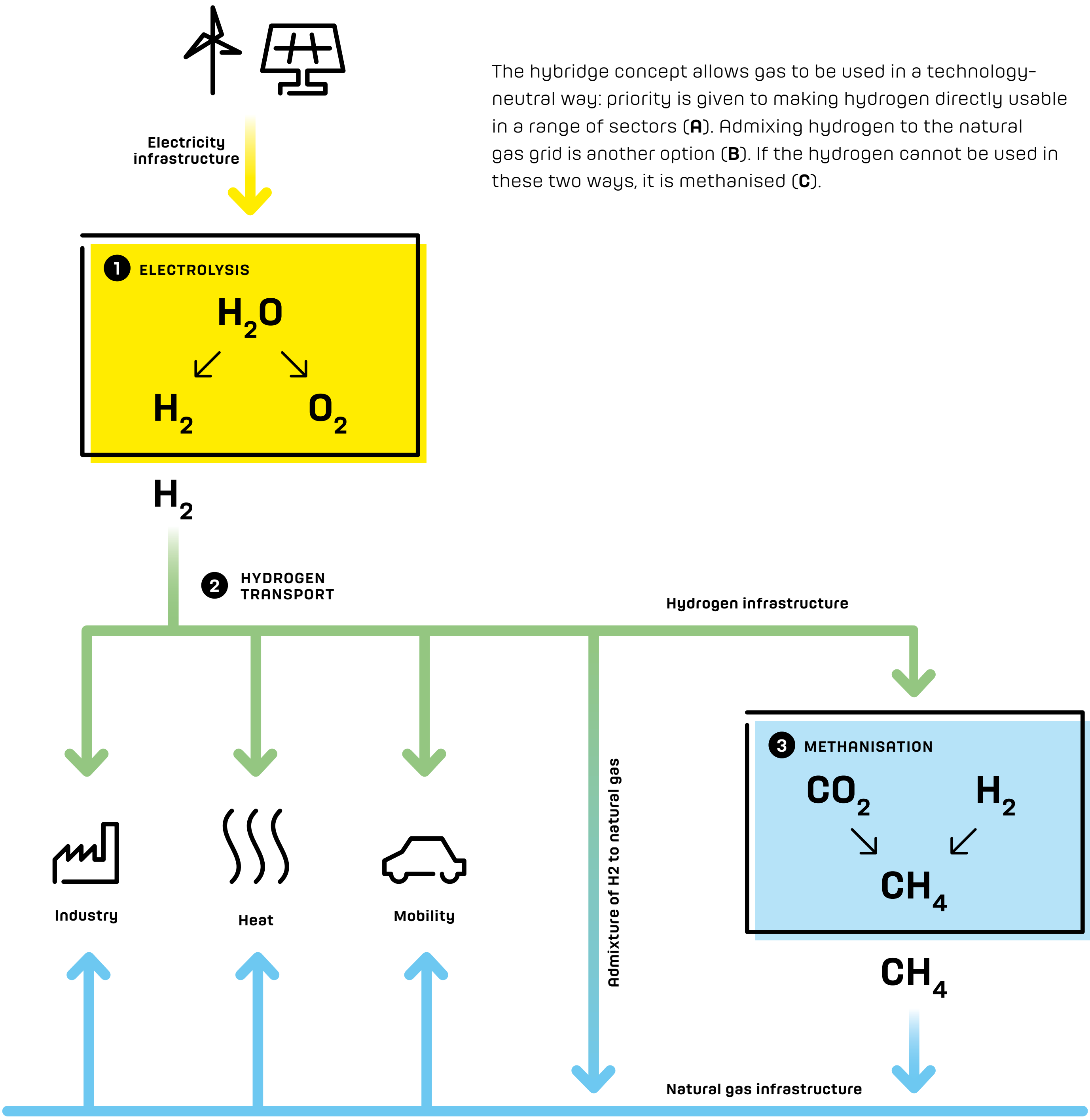
Like natural gas, hydrogen is a combustible gas that can be handled very safely. This is demonstrated, for example, by a hydrogen pipeline system in the Rhine-Ruhr region with a length of 240 kilometres, which has been operated safely for decades.

❸ Methanation

The conversion of hydrogen into methane requires carbon dioxide (CO2). This is obtained, for example, from exhaust gases resulting from industrial processes or biogenic-fuelled power plants. If green hydrogen and green carbon dioxide are used for the reaction, the result is green methane. Since natural gas consists mainly of methane, the properties of both substances are comparable. Methane can therefore be easily fed into the existing natural gas network, transported and stored in existing gas storage facilities.

REROUTING ELECTRICITY TO THE GAS SECTOR

The hybridge concept allows gas to be used in a technology-neutral way: priority is given to making hydrogen directly usable in a range of sectors (**A**). Admixing hydrogen to the natural gas grid is another option (**B**). If the hydrogen cannot be used in these two ways, it is methanised (**C**).



A STANDALONE USE OF HYDROGEN

B ADMIXTURE OF HYDROGEN TO NATURAL GAS GRID

C METHANISATION

Project partners

Amprion

Amprion GmbH is a transmission system operator headquartered in Dortmund, Germany. The company's 11,000 kilometre transmission grid connects electricity producers and consumers from Lower Saxony to the Alps – in an area in which around one third of Germany's economic output is generated. Amprion makes its network available to industrial customers and also to distribution system operators, electricity traders and producers via around 1,000 feed-in and feed-out points – with non-discriminatory access and at market prices. In the course of the transition to renewable energy, Amprion is preparing to transport increasing quantities of electricity generated from renewable energy sources and will invest more than nine billion euros in the upgrading and construction of new power lines in the coming decade. In addition, the grid operator is already working on developing innovations for the energy world of tomorrow. The focus is on efficient, sustainable and people-friendly solutions that help to ensure the stability and reliability of the transmission grid in future too.

↗ www.amprion.net

Open Grid Europe

Headquartered in Essen, Germany, OGE operates the longest gas transmission network in Germany with a length of around 12,000 kilometres. This roughly corresponds to the length of the German motorway network. The company ensures safe, environmentally friendly and customer-focused gas transport throughout Germany and, in cooperation with European transmission system operators, creates the conditions for cross-border transport and trade. The core business of the gas network operator includes the planning, construction and operation of pipelines. In addition, OGE takes responsibility for actively supporting the German energy transition – by improving existing infrastructures and developing innovative solutions.

↗ www.open-grid-europe.com

amprion

Open Grid Europe
The Gas Wheel

Contact

Amprion GmbH

Robert-Schuman-Str. 7
44263 Dortmund
Germany
Phone: +49 231 5849-14109
E-mail: info@amprion.net

Thomas Wiede

Head of Corporate Communications
and Digital Media
Phone: +49 231 5849-13679
E-mail: thomas.wiede@amprion.net

Open Grid Europe GmbH

Kallenbergstraße 5
45141 Essen
Germany
Phone: +49 201 3642-0
E-mail: info@open-grid-europe.com

Alexander Land

Head of Communications and Energy Policy
Phone: +49 201 3642-12620
E-mail: alexander.land@open-grid-europe.com

For more information visit:

www.hybridge.net

Publication Details

Publisher

Amprion GmbH
E-mail: info@amprion.net
www.amprion.net

June 2019

Design

3st kommunikation, Mainz

Printed by

Woeste Druck, Essen

climate neutral print
www.klima-druck.de
ID-No. 1979538
bvdm.

MIX
Paper from responsible sources
FSC® C006990