# Research, development and innovation

## Research and development: Goals

The goal of our research and development is to identify technological trends at an early stage, assess their economic potential and build up expertise in the business units. For this purpose, we carry out pilot and demonstration projects together with partners or customers directly at the site of their subsequent application. This ensures that successful research projects deliver innovations for our company.

Research, development and innovation also lead to inventions and patents in many cases. The portfolio of patents grew by one patent (previous year: -20) in 2021; the EnBW Group thus held 225 patents (previous year: 224) at the end of the year. The patents held by EnBW focus mainly on the areas of renewable generation, gas and electromobility.

## Research and development: Selected activities

Further information on the **floating wind power plant Nezzy²** can be found on our website.

Online ↗

**Wind energy:** Offshore wind power plants with fixed foundations are limited to shallow waters with water depths of up to around 50 m. Floating platforms could be used to install wind turbines in deeper waters. In cooperation with partners, we are investigating several different concepts for floating offshore wind farm projects that would be suitable for opening up new international offshore wind energy regions. In cooperation with the engineering company aerodyn from northern Germany, we have tested a 1:10 scale model of a new design for floating wind turbines called **Nezzy²**, which proved to be storm-proof even under real conditions in the Baltic Sea in 2020. In 2021, the design was optimized and tailored for the next phase of the project: a 1:1 scale model for the test site in the South China Sea and another possible site in the North Sea. It was possible to reduce the weight of the entire turbine by 500 t, while at the same time, improving its nominal output by up to 25%, depending on the location. The aim is to test the 1:1 model in 2022. We had planned to test a different floating foundation together with another European company in the Irish Sea in 2023 but the test was delayed once again and it is now highly likely that it will be impossible to complete it on time even at an alternative site. We will thus be discussing how to proceed with the project in the next few months. Floating foundations remain an important element for the implementation of our offshore strategy and will thus also be the subject of further research activities in the future.

**Photovoltaics:** Our subsidiary EnPV, which was founded in December 2017, is working on the commercialization of the research results from a joint project with the University of Stuttgart. In 2021, it enhanced the design for **powerful non-toxic silicon solar cells** and developed a construction plan for the very efficient and inexpensive production of the cells. In October 2021, EnPV signed a letter of intent with an international cell producer to examine the possibility of jointly producing the cells in Europe.

Further information on the **Hardt geothermal project** can be found here.

Online ↗

**Geothermal energy:** In addition to the production of electricity, geothermal energy has the potential to reduce the use of fossil fuels in heating networks. We support our business partners, such as local authorities, in decarbonizing their **heating networks using geothermal energy.** In August 2020, our joint bid with MVV for an exploration project to the south of Mannheim was accepted by the State Agency for Geology, Raw Materials and Mining (LGRB). The two companies founded the company **GeoHardt for this purpose at the beginning of 2021.** This company examined the geophysical conditions in the area in 2021 and processed the results in a simulation model that can be used to identify suitable sites in discussion with stakeholders such as local authorities, associations and citizens. A geothermal plant in Bruchsal – operated jointly with the company Stadtwerke Bruchsal – has now been reliably supplying geothermal heat to a nearby police station for the third heating season in a row. Following a long modernization phase, it was also possible to place the electricity generation plant back into operation in 2021.

Find out more about the **hydrogen projects in Wyhlen** here.

Online ↗

**Hydrogen from renewable energies:** We also want to provide our customers with carbon-neutral gaseous energy sources in the long term. We are carrying out research in this field in the two projects "alkaline hydrogen electrolysis plant" and "$H_2$Mare." The **alkaline hydrogen electrolysis plant in Wyhlen** has been operated by our subsidiary Energiedienst (ED) with funding from the State of Baden-Württemberg using electricity generated from hydropower since 2018. In the reporting year, ED started work on expanding the capacity of the plant by 5 MW to 6 MW as part of the "Reallabore" tender process from the German Federal Ministry for Economic Affairs and Energy (BMWi) with the

aim of supplying a district, as well as industry and customers in the mobility sector, with hydrogen produced from green electricity. The plant in Wyhlen is thus now the largest power-to-gas plant in southern Germany. In the **$H_2$Mare** project, a consortium of industry and research partners, in which EnBW is also participating, is carrying out research into the production of green hydrogen directly in offshore wind power plants. We want to develop the skills we will need to also construct and operate hydrogen plants at wind power plant sites in the future, although regulatory and economic aspects are also important. In four different subprojects with a total of 35 partners, $H_2$Mare will lay the groundwork to become a technological leader in this field in just four years. The aim is to support the climate targets by speeding up the decarbonization of the industry, heating and transport sectors. Our main priority is to gain experience in hydrogen logistics and the electrolysis of saltwater out at sea. We are thus taking a big step forward on the path to generating affordable green hydrogen.

Further information on the **"Hydrogen Island Öhringen"** project can be found on our website.

Online ↗

**Hydrogen in the gas grid:** Our subsidiary Netze BW started a pilot project called the **"Hydrogen Island Öhringen" in 2020 in the City of Öhringen in the Hohenlohe district that is unique across Germany.** A section of the existing natural gas grid is being disconnected and will be supplied independently. The conversion work should be completed at the beginning of 2022. A natural gas mix with a green hydrogen content of up to 30% will be used in the island grid. The hydrogen will be produced with the aid of an electrolyzer on the premises of Netze BW. In a first stage, the company building has already been supplied with a hydrogen/natural gas mix since December 2021. This project will run for several years and aims to demonstrate that the natural gas grid can be decarbonized using zero-emission energy sources – just like the electricity grid. At the field laboratory **"Energy Park Bad Lauchstädt"** in the middle of Germany, we are investigating the entire value added chain for green hydrogen on a large industrial scale, from its production and transport through to its storage and application, in a project led by VNG. A main focus will be testing the storage of the hydrogen in an underground salt cavern. The project was awarded funding from the German Federal Ministry for Economic Affairs and Energy in 2021. The field laboratory in Bad Lauchstädt was also selected by the European Clean Hydrogen Alliance as one of the projects to establish a European hydrogen industry. The European Clean Hydrogen Alliance was founded in July 2020 by the EU Commission to support the EU's hydrogen strategy with the aim of stimulating the rollout of clean hydrogen production and use in Europe.

The **"Energy Park Bad Lauchstädt"** is a demonstration of the entire value added chain for hydrogen.

Online ↗

**Internal carbon pricing:** Internal $CO_2$ pricing is an emerging method for reducing a company's own emissions. A corresponding model for EnBW was developed as part of a dissertation at the Sustainability Center Freiburg. Using case studies on internal $CO_2$ pricing in real estate, catering/canteens and mobility, the project is demonstrating how, even outside of the area of energy generation, internal processes can make an important contribution to reducing $CO_2$ emissions and how pricing can provide useful incentives.

Further information on **integrating electromobility into the grid** can be found on our website.

Online ↗

**E-mobility in rural areas:** Our subsidiary Netze BW has analyzed what impact the charging of e-cars can have on rural electricity grids in the "E-Mobility-Chaussee" grid laboratory. The operational tests were concluded in July 2021. During an 18-month practical test, we gained important insights into the user behavior of our customers in these regions and how electromobility can be integrated into rural distribution grids. Static and above all dynamic variants of the load management system offer the greatest potential for improving the capacity of our distribution grids for the integration of e-vehicles. The grid-friendly management of charging infrastructure using measurements of, for example, the current and voltage values, taken in real time make it possible to supply electricity to almost twice as many vehicles at peak times than in grids without optimization measures.

**Smart charging at home:** Successfully integrating electromobility into the grid will require a smart and powerful electricity grid. In view of the current dynamic scaling up of electromobility, it will be necessary to optimize the existing electricity grid to quickly increase its capacity to handle the required charging infrastructure. The fact that electric vehicles are left unused for long periods of time in the private sector will be utilized to relieve the burden on the grid and enable the flexible and scalable management of charging stations using a smart measurement system. In Netze BW's "Smart Home Charging" grid laboratory, scalable solutions are being developed and tested at various sites in different stages that build upon one another. Field tests are currently being carried out at the sites in Wangen im Allgäu and Künzelsau.

**Quick charging for trucks:** In cooperation with partners, EnBW is planning to construct a quick-charging station for heavy-duty trucks. The pilot project is part of the initiative "Pilot Charging and Filling Station Infrastructure for Long-Haul Trucks" initiated by the Federal State of Baden-Württemberg, for which EnBW signed a corresponding letter of intent in October 2021. The concept for the chosen site will be developed in 2022 and aims to set a new standard in the sector with a charging output of up to 1,000 kW per truck. The charging station will be constructed and placed into operation in 2023. The most powerful charging points for passenger cars are currently able to deliver a charging output of up to 300 kW. Our subsidiary Netze BW is using the project to investigate how the quick-charging of trucks can be integrated into planning for the electricity grid. This project expands EnBW's commitment to the task of preparing the infrastructure for the electrification of heavy goods vehicles. Megawatt charging will be tested at four sites between Berlin and the Ruhr region of Germany as part of the BMVI project HoLa (high-performance charging of trucks) between 2023 and 2025 in cooperation with a large consortium of partners from the worlds of business and science.

**Inductive charging:** Our site at the Port of Karlsruhe was connected to the public transport system with its own electric bus in 2021. The special feature of this electric bus is that the batteries are charged inductively during the journey. This charging technology involves inductive coils being embedded in the road surface. As soon as the vehicle drives over them, the receiver coils fitted on the underbody are activated. Electrical energy is generated in the coils via a magnetic field and is stored in the vehicle's battery. This enables the vehicle to cover long distances without the need to stop to recharge. We are thus testing contactless charging of the electric bus during everyday use. The contactless charging technology originates from the Israeli start-up ElectReon. The e-bus has been in regular operation since August 2021 while we continuously optimize the infrastructure in the bus and road.

Further information on the **extraction of lithium** at the Bruchsal geothermal plant can be found here.

Online ↗

**Sustainable extraction of lithium:** In cooperation with the Karlsruhe Institute of Technology (KIT) and other firms and institutes from the world of science, we are investigating a process to sustainably extract lithium from thermal water as part of a research project. In December 2020, we received funding approval for the four-year project. At existing geothermal plants – such as in Bruchsal – special carrier material will be used to selectively separate lithium from the rest of the thermal water. After successfully testing the process in the laboratory, the challenge is to transfer the process to an operating geothermal plant. The concept for the implementation in the plant at the site was developed in 2021 and several suitable carrier materials were identified. The pilot plant will be constructed during the course of 2022. Tests will then be completed to find out which carrier materials and parameters are the best for extracting the most lithium.

## Research and development: Expenditure and personnel

In the 2021 financial year, we spent €38.6 million (previous year: €70.6 million) on research and development. EnBW innovation management was no longer included in the figures in 2021 because the gradual growth in revenues and the funds deployed for this purpose are distorting the presentation of expenditure on research and development. Adjusted for this change, expenditure on research and development increased in 2021 by 15.2% (previous year restated: €33.5 million). As in the previous year, we received government research grants of €1.0 million. There were a total of 66 employees in areas dedicated to research and development at the Group (previous year: 93 employees). In addition, 253 employees (previous year: 185 employees) were involved in research and development projects as part of their operational work.

**+15.2%**

increase in expenditure on **research and development** compared to the previous year.

**Expenditure on research and development**

| in € million | 2021 | 2020 |
|---|---|---|
| Grids | 18.8 | 16.0 |
| Generation from renewables | 5.2 | 7.0 |
| Smart energy world, storage and electromobility | 7.1 | 5.9 |
| Hydrogen | 6.5 | 1.8 |
| Dismantling | 0.0 | 1.4 |
| Customer-related research projects | 0.7 | 0.9 |
| Other | 0.3 | 0.6 |
| **Total**[1] | **38.6** | **33.5** |

1 The figures may not add up due to rounding differences. The figures for the previous year have been restated.

EnBW has been awarded the **Digital Lab Award 2021,** again making it one of the best digital innovation laboratories in Germany.

Online ↗

## Innovation management

**EnBW Innovation** has been an integral part of the Group since 2014. In partnership with committed company founders, investors and employees, we develop new business models related to the key themes of Smart Grid, Digital Energy Management & Trading, Connected Home, Mobility, Urban Infrastructure and Telecommunications & Data Solutions. The **innovation strategy** focuses on two main approaches: the generation and scaling up of new business models and investments in external start-ups by EnBW New Ventures.

Jürgen Stein, Head of EnBW Innovation, explains **how an idea can be turned into a company.**

Online ↗

Networking and transformation were the **main areas of focus** for EnBW Innovation in the last few months. For this purpose, we defined six relevant search fields for new business and streamlined the innovation portfolio. The acquisition of the majority shareholding in DZ-4 in June 2021 was one of the resulting measures. DZ-4 is the market leader for the leasing of solar power plants and battery storage systems and has been part of the ENV portfolio since 2015. We also intensified our networking activities both inside and outside of EnBW. The result: a great willingness to cooperate, interdepartmental collaboration in the Group and a regular exchange of ideas and information – above all with research and development and the Digital Office. To improve our networking outside of the company even further, we organized the first **Innovation Challenge** in April 2021. The winners received a start-up grant from EnBW.

ENV was the first German venture capital company to be awarded the **Diversity VC Standard.**

Online ↗

**EnBW New Ventures (ENV)** invests in start-ups that develop sustainable and mostly digital solutions for infrastructures. The aim is to use the total initial investment volume of €100 million to secure minority shareholdings of between 10% and 30% in up to 20 start-ups, with an investment period of four to eight years in each case. It has a closed business model (evergreen structure) and any profits generated are invested in new start-ups. ENV plays the role of an active investor, supports the start-ups as a business coach or kind of "sparring partner" and is represented on their boards. The start-ups receive access to professional investor expertise via ENV. In addition, commercial cooperation with the operating units at EnBW is also possible. ENV was able to successfully conclude its first two exits in 2021 with Lumenaza and Replex.

## Innovation: Selected activities

EnBW Innovation founded two start-ups in 2021: **Parconomy** works with cities and local authorities to transform parking management and thus reduce the environmental pollution caused by cars in cities. An open roaming platform is used to digitally manage access to parking spaces in Germany, and possibly across Europe in the future, and enables cashless payment for their use. The start-up **Switchboard** offers an online marketplace for programming interfaces or so-called APIs. Companies can use the marketplace to buy and sell solutions. Switchboard is initially offering an API for photovoltaic yield forecasts. It was developed by EnBW and makes it possible to reliably forecast the electrical output of PV power plants. Other interfaces and services are planned.

The founder of Switchboard tells us **how her start-up can contribute to the Energiewende.**

Online ↗

The **solar power plants** on the roofs of the EnBW charging parks are part of the **virtual power plant.**

Online ↗

One of the major challenges of the Energiewende is the transition from just a few central conventional power plants to many millions of decentralized renewable energy power plants. We are exploiting the possibilities offered by digitalization to develop a future-oriented solution: Our **virtual power plant** unites many small power plants such as wind turbines, photovoltaic power plants, CHP power plants and hydrogen power plants via a digital platform and joins them together in a network. The "amassed" green electricity is then sold on the electricity markets for the benefit of customers. In 2021, the virtual power plant grew from 2,000 power plants to over 5,000 power plants with a total capacity of more than 2 GW. The solar power plants at the EnBW charging parks also belong to the virtual power plant.