

# Research, development and innovation

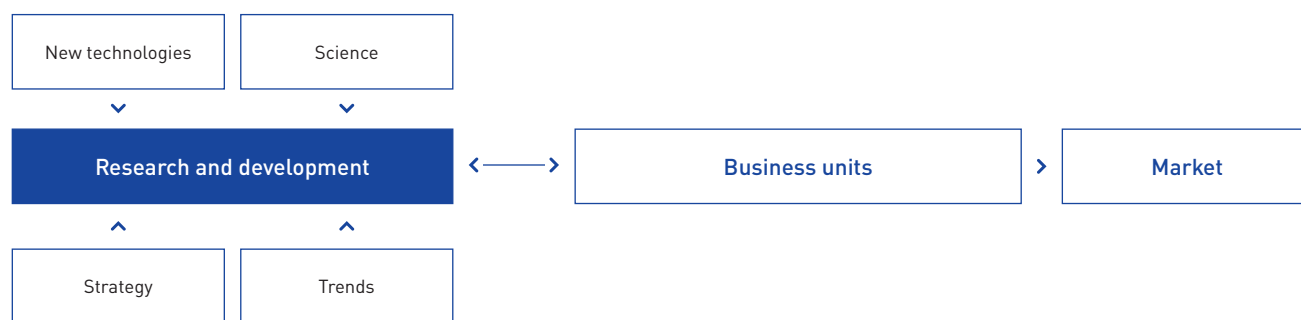
## Research and development: Goals, guidelines and processes

The goal of research and development at EnBW is to identify important trends and technological developments at an early stage and to develop new skills for future business activities in pilot and demonstration projects. For this purpose, research projects are carried out in collaboration with the operational units at EnBW or with customers – directly at the site of their subsequent application. They form a project portfolio that is

centrally coordinated for all EnBW units. This ensures that successful research projects deliver innovations for EnBW. The research and development activities are integrated into an external and internal network of partners.

Research, development and innovation also leads in many cases to inventions and patents. The portfolio of patents grew by 25 patents (previous year: nine) in 2018; the EnBW Group held 208 patents (previous year: 183) at the end of the year. The patents held by EnBW focus mainly on the areas of generation and grids.

### The research process at EnBW



## Research and development: Key points and selected results

Research and development at EnBW focuses on renewable energies, green gases and storage systems for the smart digital energy world.

### Renewable Energies

**Wind energy:** Offshore wind power plants with fixed foundations are limited to shallow waters. Floating platforms could be used to exploit the wind power potential in deeper waters. In cooperation with partners, EnBW is investigating various different concepts for **floating offshore wind farm projects** that would be suitable for opening up new international offshore wind energy regions. In the reporting year, negotiations about an investment in a Danish floating platform concept did not result in an agreement. Alternatives will now be investigated.

In addition, EnBW is a member of a consortium headed by the manufacturer Senvion that aims to design a **prototype for an offshore power plant with an output of more than 10 MW** and construct it as a pilot plant with funding from the EU. Larger wind turbines are a prerequisite for further reducing the cost of

generating electricity in offshore wind farms. In expectation of these developments, bids were already submitted in the latest auctions that forgo funding via guaranteed feed-in remuneration. The competitiveness of offshore wind energy on the electricity market has thus increased further. The project began in 2018 with the design of the prototype and will run until 2021.

**Artificial intelligence (AI)** is a key technology of the future and is concerned with the automation of intelligent behaviour. It uses self-learning algorithms that adapt their behaviour based on experience gained during earlier computations and so learn to independently solve problems. EnBW is developing AI expertise along the whole value added chain with the aim of exploiting the significant competitive advantages on offer. For example, EnBW has developed **ADAZ (Application for Diagnosis, Analysis and Status Monitoring)** for the early identification of technical damage to wind power plants and to help avoid any subsequent damage. The system evaluates data at sampling rates of up to 50,000 pieces of data per second. It is thus possible to identify damage early and reduce repair costs. Wind power plants with a total output of 720 MW were already monitored by ADAZ in 2018. Savings of several millions of euros were achieved as a result. The services provided by ADAZ have already been marketed externally. In addition, a pilot project is being completed for a large, potential customer.

**Photovoltaics:** The University of Stuttgart has developed a laser process that enables the inexpensive production of non-toxic silicon solar cells with a high level of efficiency. These cells achieve higher efficiency because the electrical connections are all made at the rear of the cell and there are no contacts on the front which could shade some of the incident light. EnBW has been cooperating in this government-funded research project since August 2017. An efficiency of more than 22% was achieved using 16 inch cells for the first time in 2018. The EnBW subsidiary EnPV – founded in December 2017 – has started work on marketing the patented process.

**Geothermal energy:** The partners Électricité de Strasbourg and EnBW jointly operate the Soultz-sous-Forêts geothermal power plant in the Alsace region that uses a well-researched geothermal reservoir at a depth of 5,000 metres. The gross electrical output of the power plant is 1.7 MW. In 2018, the power plant generated 7.7 GWh of electricity as in the previous year with an availability of 96% (8,400 operating hours, previous year: 90%, corresponds to 7,900 operating hours). In cooperation with the company Stadtwerke Bruchsal GmbH, EnBW has been operating the Bruchsal geothermal power station since 2009. The demonstration plant generates electricity with a nominal output of 0.5 MW using 120 degree hot thermal water pumped from a depth of 2,500 metres. The power plant not only generates electricity but also district heating from geothermal energy for a public facility. The heating circuit was constructed in 2018 and will be placed into operation at the beginning of 2019. EnBW is thus expanding its geothermal expertise to include the supply of heating to customers.

### Green gases

We also want to provide our customers with carbon-neutral gaseous energy sources in the long term. EnBW started a Group project in 2018 to identify the necessary steps towards a gas supply that will reduce CO<sub>2</sub> emissions from fossil fuels by 2030 and assess the technological possibilities for the period afterwards. The experience gained from various pilot and demonstration projects will help us achieve this. With the aid of government and state funding, EnBW carried out research into the fuelling infrastructure required for quick fuelling at a pressure of up to 700 bar and that incorporates flexible hydrogen electrolysis, most recently for buses in Stuttgart, at **hydrogen filling stations** in Karlsruhe and Stuttgart from 2011 to 2018. Since the beginning of 2019, the EnBW subsidiary ZEAG has been generating **green hydrogen** with the aid of state funding. It is using a 1 MW PEM electrolyser (PEM = proton exchange membrane) that converts green electricity from the “Harthäuser Wald” wind farm into green hydrogen. The green hydrogen is used in mobility initiatives in Baden-Württemberg, for generating heat at combined heat and power plants and at the rocket test rig at the German Aerospace Center (DLR) in nearby Lampoldshausen. Energiedienst Holding (ED) already opened an alkaline **hydrogen electrolysis plant** with an electrical output of 1 MW in Wyhlen in November 2018 – operated with green hydropower. The target market is the transport sector.

In the Biohybrid project, the EnBW subsidiary Erdgas Südwest has developed a concept to make biogas with the quality of natural gas available anywhere where customers may require

electricity and heating without CO<sub>2</sub> emissions from fossil fuels. The key concept behind Biohybrid is to store biomethane in liquid form and feed it back into the gas grid as required. As a liquid fuel, Bio-LNG (LNG = liquefied natural gas) is also suitable for use in the transport sector. A market exists for Bio-LNG due to the current situation regarding CO<sub>2</sub> emissions. The company is currently looking for suitable sites in Baden-Württemberg for the first **Biohybrid plant**. The EnBW subsidiary bmp greengas is already handling the marketing of biogas products. A pilot project to examine the opportunities offered by carbon-neutral liquid energy sources will be carried out by ED and is currently at the detailed planning stage. In cooperation with its partners, the aim is to produce synthetic diesel and paraffin using CO<sub>2</sub> and hydrogen in Laufenburg. The approval for construction was given in 2018.

### Storage systems for the smart digital energy world

**Load management for electromobility:** Our subsidiary Netze BW started the NETZlabor “E-Mobility Avenue” in Ostfildern near Stuttgart in 2018. Customers in the same street with eleven electric cars, a home storage system and a grid battery are helping us simulate a future centred on electromobility and enabling us to analyse user behaviour and the state of the grid. We can use this information to develop concepts for the efficient operation of the grid and to better exploit the mobile and fixed storage systems for smart electricity grids.

**New technologies for the charging infrastructure:** The EnBW Group is also investigating alternatives for electrifying transport: A test track for electrical **HGV goods traffic with overhead power lines** will be developed in the district of Rastatt between Gernsbach-Obertsrot and Kuppenheim by the end of 2019. Our grid subsidiary Netze BW is a strategic partner in the “eWayBW” project which will be run by the Transport Ministry of Baden-Württemberg until 2022. At the same time, EnBW is also working on **induction systems**. A feasibility study conducted together with the Karlsruhe Institute of Technology (KIT) concluded in 2018 that alternative operating strategies could make contactless charging via the road as the vehicle drives along it an attractive proposition. The research into these new possibilities is being continued.

**Storage systems for commercial customers:** EnBW cooperated in a demonstration project with the storage system supplier ads-tec, the solar experts from Pohlen Solar and the retail company Aldi Süd until 2018 to find out how the discount store could use even more self-generated solar electricity in their branches. The project has now been successfully concluded and has demonstrated that the shops can increase their own solar consumption even further using battery storage systems. The challenge is to guarantee the economic efficiency of the system against today’s prices for storage systems and energy. In this practical test, EnBW was able to demonstrate the great potential offered by solar power plants in combination with storage systems depending on the control algorithms used.

**Storage systems for household customers:** In autumn 2016, three household customers were fitted with storage systems in order to develop a smart control system that can adapt to the availability of electricity on the grid and postpone the times

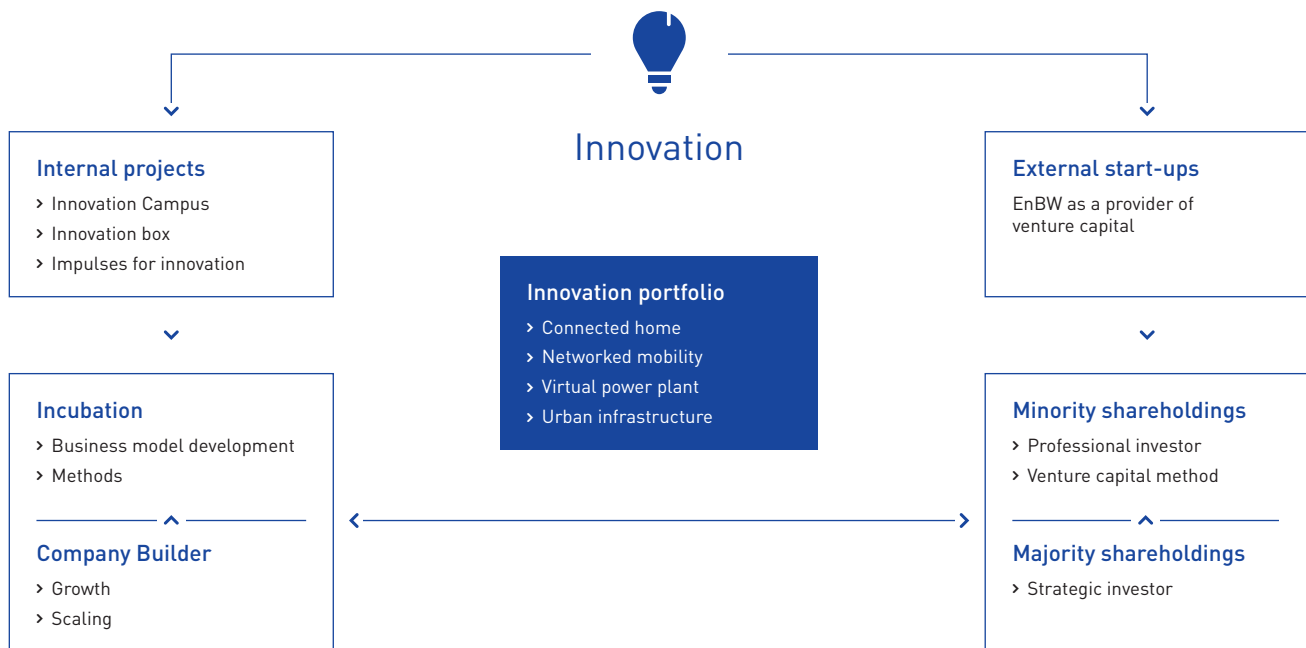
electricity is drawn from the grid without any loss in comfort. The project ended in June 2018 after running for two years. It has demonstrated that by using good battery management many households could significantly shift the times at which they draw electricity. The results from these storage projects with customers will also flow into the development of commercial products from our subsidiary SENEK, which EnBW acquired in 2018.

**Power plant storage systems:** Cross-sector considerations on how storage systems can provide added value led to a co-operation with Bosch to develop battery solutions for the energy market. The large 5 MW battery installed at the Heilbronn coal power plant was inaugurated in April 2018. It enables the power plant to respond even better to fluctuating decentralised feed-ins. EnBW is responsible for the marketing of the stored energy in this joint venture.

Beyond the main focal areas of renewable energies, green gases and storage systems, EnBW is also pursuing interesting individual projects such as **phosphate recycling**: In cooperation with its subsidiary MSE Mobile Schlammentwässerungs GmbH, EnBW has developed a process to recover phosphorous in mobile units at sewage treatment plants before the dewatered sludge is incinerated in power plants. Phosphorous is essential for plant growth but is in scarce supply in Germany. Following successful tests at seven sewage treatment plants, MSE concluded contracts for the recovery of phosphorous with two local authorities in Baden-Württemberg and North Rhine-Westphalia in 2018. Customers are thus offered resource-conserving recycling of sludge in accordance with the revised German Sewage Sludge Ordinance. The magnesium ammonium phosphate recovered in the process is a valuable plant fertiliser ([www.mse-mobile.de](http://www.mse-mobile.de)).

## Innovation management: Goals, guidelines and processes

### The innovation process at EnBW



EnBW develops new business models outside of its core business through central innovation management in order to quickly identify new sources of revenue for the Group and bring them to the market. The innovation strategy focuses on two main approaches: the internal generation and scaling up of new business models in internal projects and investments in external start-ups by EnBW New Ventures GmbH. Following the successful development of new business models, the EnBW start-up teams then face new challenges in the growth and scaling up phase. In order to efficiently support teams during this phase, innovation management has established the Company Builder: It provides start-ups with additional skills in the form of controlling, sales and marketing experts so that the start-ups can optimise their products and position them on the market. For the refinement of existing sales channels or the development of

new ones, support is also given in the areas of process automation and cost optimisation.

**EnBW New Ventures** invests in start-ups that are driving the converging markets for energy, mobility and urban living. It focuses on companies who realise value added through scalable business models and new technologies. The aim is to use the total available investment volume of €100 million to secure minority shareholdings of between 10% and 30% in up to 20 start-ups. EnBW New Ventures 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. Via EnBW New Ventures, the start-ups receive access to professional investor expertise and to a customer and supplier network on the energy market. In addition, commercial cooperation with

the operating units at EnBW is also possible. In order to target substantial growth, EnBW will in future, beyond the activities of EnBW New Ventures, also invest in start-ups which already have a tested business model and a successfully launched range of products/services.

## Innovation: Key points and selected results

**Virtual power plant** (Glossary, p. 155): The energy system is being transformed into an ecosystem of numerous small and decentralised power plants that generate, save or consume electricity: photovoltaic power plants, wind turbines, batteries, electric vehicles and heat pumps. This produces complex energy networks that demand new skills. EnBW is utilising its expertise gained from the operation of highly complex systems and is transferring this knowledge to the development of new business models and a digital platform. The activities carried out by EnBW also include direct distribution of even the smallest regenerative power plants, electricity communities (P2P), digital trading access, dynamic tariffs and flexibility management.

Both the business models and the platform are designed so that new themes can be quickly added, existing skills from the stock of business models can be quickly recombined and a modern digital process landscape is maintained right from the beginning. Direct distribution enables customers to sell their own electricity – which will become the norm after EEG funding ceases. Alongside the established small-scale activities, the project has now developed a portfolio of more than 250 MW and has hundreds of customers. The flexibility management system controls the loads so that added value is generated for both customers and the energy system. Digital trading access ensures that even small companies will be able to benefit from the fluctuating and in some case negative prices on the market. This is where the superchargers from EnBW – currently consisting of more than 110 high-performance charging stations – are connected up, networked and supplied with electricity. Access for around 600 units is contractually guaranteed. Electricity communities bring together electricity generators and consumers from within the same region or bring them together virtually so that the community is able to collectively use and share electricity from a specific source. EnBW has already established numerous regional clusters of this kind in cooperation with the start-up Lumeneza, part of the EnBW New Ventures portfolio.

**First micro business unit:** In order to offer campus projects from EnBW better opportunities for growth, innovation management has created the concept of internal spin-offs in cooperation with

the compliance and data protection department (p. 58). Mature projects with marketable business models that are in line with the EnBW strategy and have already generated their first sales can now be spun-off into so-called “micro business units”. SMIGHT – the first micro business unit – was launched in May 2018 and it has now evolved from a campus project to an independent business unit. A new system of corporate governance in the form of the so-called “Basic Rules” has been created for the micro business units. The special feature of the Basic Rules is that as a micro business unit, SMIGHT can take advantage of Group services offered by EnBW such as legal advice or purchasing and IT services. On the one hand, the rules create the necessary scope for the further development of the business model, while on the other hand, they are subject to certain fixed targets and guidelines set by innovation management. The SMIGHT team have been able to almost triple their revenue between 2017 and 2018 as a result.

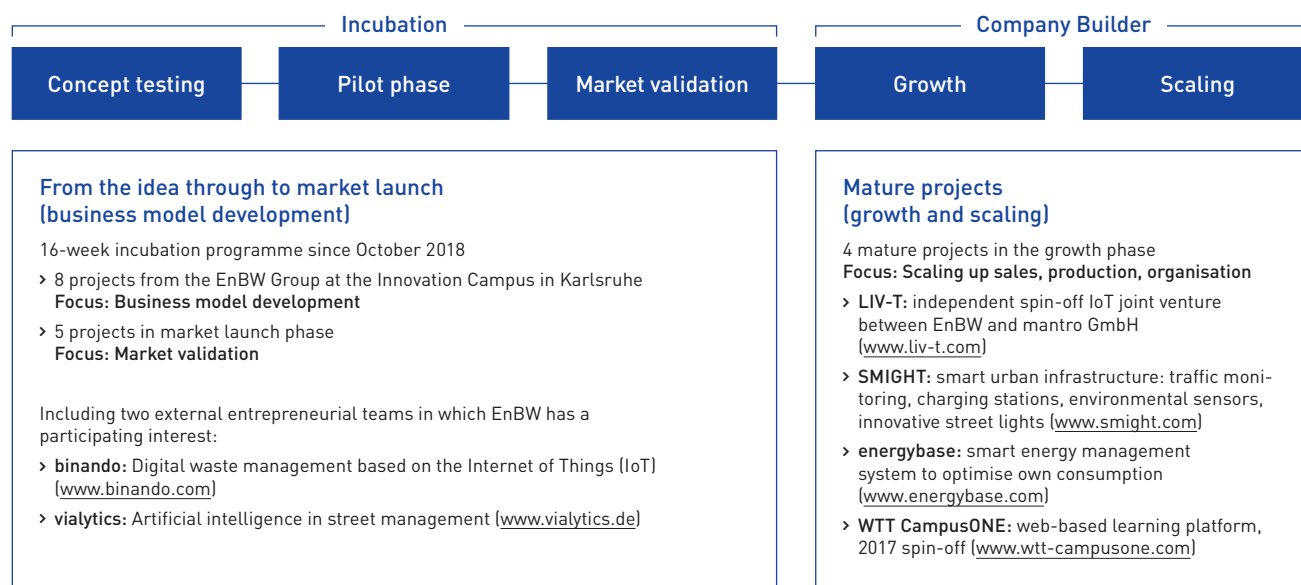
**EnBW incubation programme:** EnBW innovation management supports start-up projects during the incubation phase from the initial idea through to market launch and accompanies mature projects during the growth and scaling up phase with the Company Builder. A total of more than 30 start-up projects have been set up, put to the test, refined and in some cases rejected in the past four years. The aim is now to make the innovation process even more efficient and stringent with a new programme. Eight EnBW projects are currently participating in the so-called “16 to the power 4 incubation programme”, which was launched at the Innovation Campus in Karlsruhe on 1 October 2018. External teams have also been able to apply to join the programme since January 2019 ([www.sparkthefuture.de](http://www.sparkthefuture.de)).

Five other projects have already completed the first incubation phase and are now at the market launch phase. They include two external company teams: binando who develop solutions for the digital management of waste based on the Internet-of-Things (IoT) and vialytics who develop artificial intelligence solutions for street management.

Four mature projects are currently in the growth phase:

- > LIV-T – an independent spin-off joint venture from EnBW and mantra GmbH that develops data-based Internet of things (IoT) products that allow the energy infrastructure in buildings to be intelligently networked
- > SMIGHT – a project that equips existing infrastructure such as street lighting, transformer stations or charging stations with sensors to optimise traffic flows, monitor the electricity grid or provide information on free parking spaces
- > energybase – a smart energy management system used to optimise energy consumption
- > WTT CampusONE – the award-winning digital learning platform

## Innovation management: projects at incubation and market maturity stages



The holistic approach followed by EnBW innovation management was awarded the rating “very good” by the magazine “Capital” in 2018 for its stringency and depth.

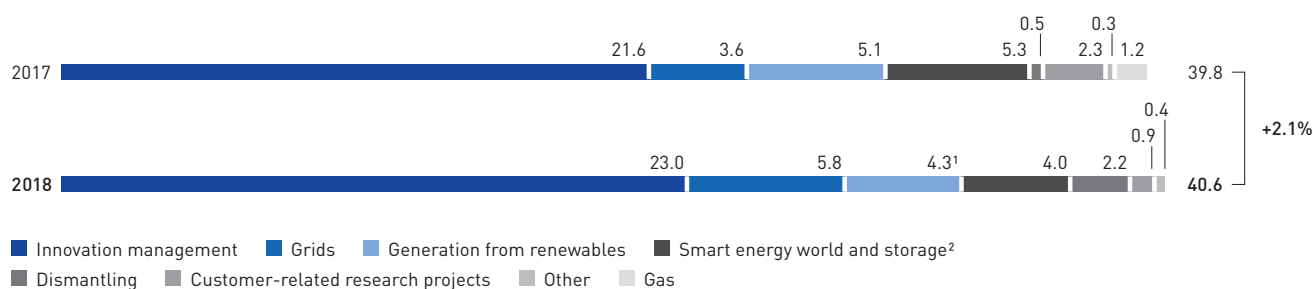
**Urban infrastructure:** At the first EnBW Innovation Conference that was held in September 2018 at the Innovation Campus in Karlsruhe, the EnBW Group and selected start-ups presented innovative solutions for the city of tomorrow. EnBW used the event to demonstrate the innovative strength at the company and to show what the Group has in common with the world of start-ups. Especially against the background of the future transformation of EnBW into an urban infrastructure supplier, EnBW subsidiaries and cooperation partners were also included in the search for urban innovations. A concept that proved a big hit: More than 30 exhibitors presented their solutions for the city of tomorrow at the end of the event to around 500 guests from business, politics and the start-up scene. The exhibition was accompanied by a series of talks featuring renowned guest speakers.

## Expenditure and personnel

The EnBW Group spent €40.6 million (previous year: €39.8 million) on research, development and innovation in the 2018 financial year. In contrast, the income generated by innovation management stood at €6.4 million. The Group received government research grants of €2.3 million (previous year: €2.9 million). There were 63 employees (previous year: 61) in the areas of research, development and innovation in 2018. 169 employees (previous year: 193 employees) were involved in research and development projects as part of their operational work. A further 110 employees (previous year: 105) were involved in innovation projects.

## Expenditure on research, development and innovation

in € million



1 Also includes green gases.

2 Includes e.g. electromobility and hydrogen mobility.