Federal Ministry
for Economic Affairs
and Energy

Energiewende
Switch to the Future

The energy transition – a great piece of work

Innovation Through Research

Renewable Energies and Energy Efficiency:
Projects and Results of Research Funding in 2014

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Foreword

Germany has chosen a safe, environmentally friendly and economically successful energy system with its change in energy policy – the German energy transition. The guiding principles of this globally unique large-scale project have been clearly defined: The expansion of renewable energies will make us more independent of traditional energy sources. At the same time, we will be able to limit total energy consumption through the efficient use of energy and thus reduce emissions of harmful greenhouse gases.

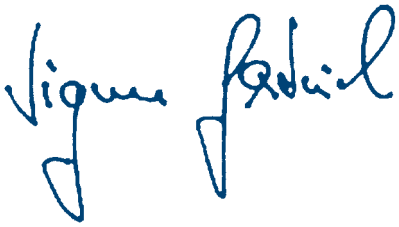
The energy system of the future will differ considerably from the current one. Some technologies that will be utilised in the future are not yet technically available, appear economically infeasible or might not even have been invented yet. In order for the energy transition to succeed, we need future-oriented research and outstanding innovations. Therefore, the Federal Ministry for Economic Affairs and Energy has made energy research a strategic element of its energy policy.

Scientists are also increasingly focussing on the bigger picture and the complex interrelationships within the energy system, which, alongside the many isolated individual issues, are becoming more and more important. It was thus logical to bring together applied energy research within the organisation of the German federal government under the Federal Ministry for Economic Affairs and Energy and thus bundle together all themes from the areas of renewable energies and energy efficiency along the entire energy chain. This makes it possible to utilise funds more efficiently and to tackle superordinate and interdisciplinary research issues more effectively.

This annual report provides information on the entire field of applied research into modern energy technologies – for the first time from one source. It includes the latest results from the areas of research and development, background information on the latest technologies and market developments, as well as selected projects which illustrate the importance and diversity of the detailed research work. The resulting findings inspire confidence that we will master the challenges facing us and make sure the energy transition will be a success.

I wish you all an interesting and stimulating read.

Yours sincerely,



Sigmar Gabriel
Federal Minister for Economic Affairs and Energy

Research and development for the energy transition

The energy concept developed by the German federal government in 2010 envisages the far-reaching restructuring of the energy supply system in Germany by 2050. Important goals in this concept are the reduction of primary energy consumption by 50 percent and increasing the proportion of renewable energies to cover 80 percent of the demand for electricity and 60 percent of the gross final energy consumption.

In 2011, the 6th Energy Research Programme "Research for an environmentally friendly, reliable and affordable energy supply" was started. The following superordinate goals are being followed in this programme:

1. Accelerating the modernisation process for the German energy supply system

2. Strengthening German business in international competition

3. Securing and expanding technological options

The 6th Energy Research Programme is oriented along the guidelines set by the energy transition. Increasing energy efficiency and renewable energy technologies has the highest priority. This is followed by storage and grid technologies, which will become increasingly important in future due to the growing use of fluctuating renewable energies. The German federal government is resolutely pursuing the 6th Energy Research Programme in this legislative period by placing an even greater focus on the energy transition than ever before. An important measure is the bundling of applied project funding in the Federal Ministry for Economic Affairs and Energy (BMWi) as a vital element of the energy policy. This opens up significant additional opportunities for utilising synergies between energy policy and energy research on the one hand, and between energy efficiency and renewable energies on the other. Moreover,

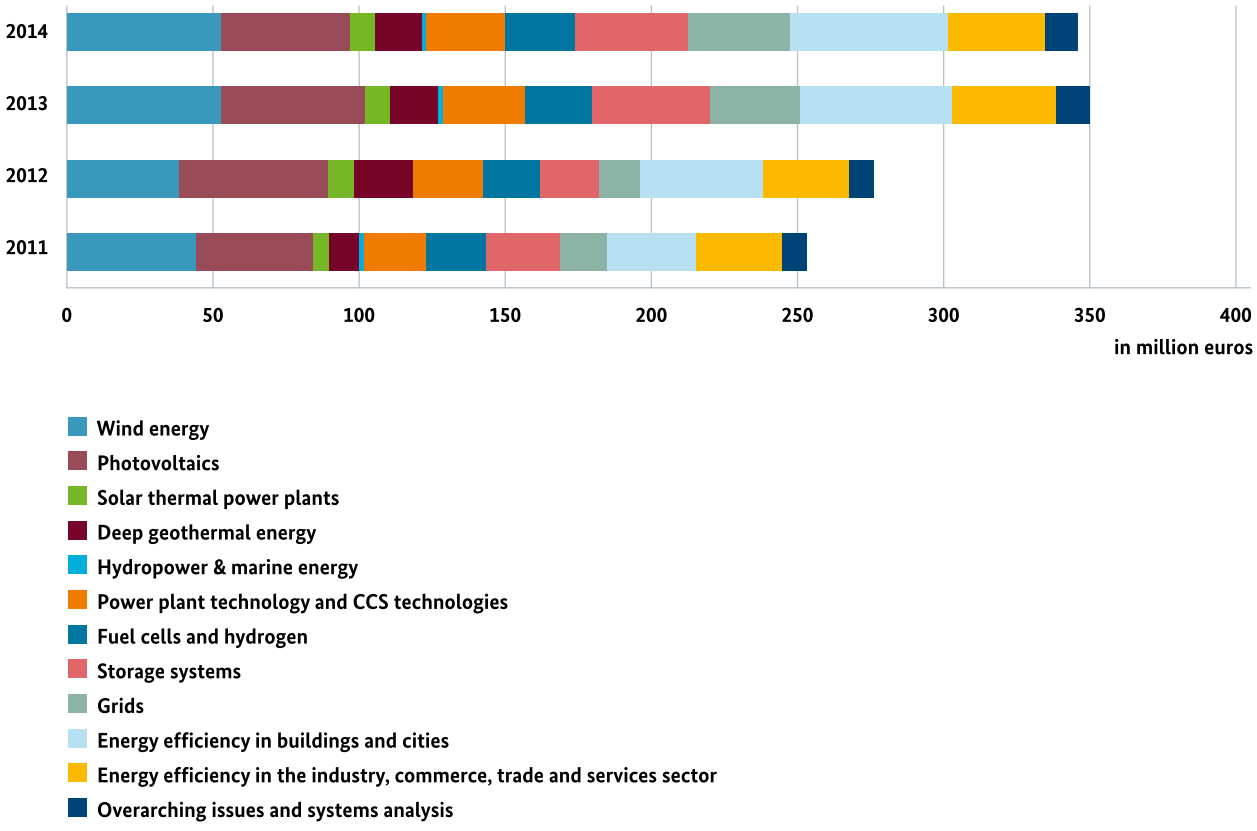
a revision of the Energy Research Programme was started in the reporting period, whereby the emphasis lies on the following factors:

- A greater concentration on system-oriented research approaches
- Expanding European networking through research cooperation
- Intensifying cooperation with the German states
- Creating transparency by setting up the central information system EnArgus

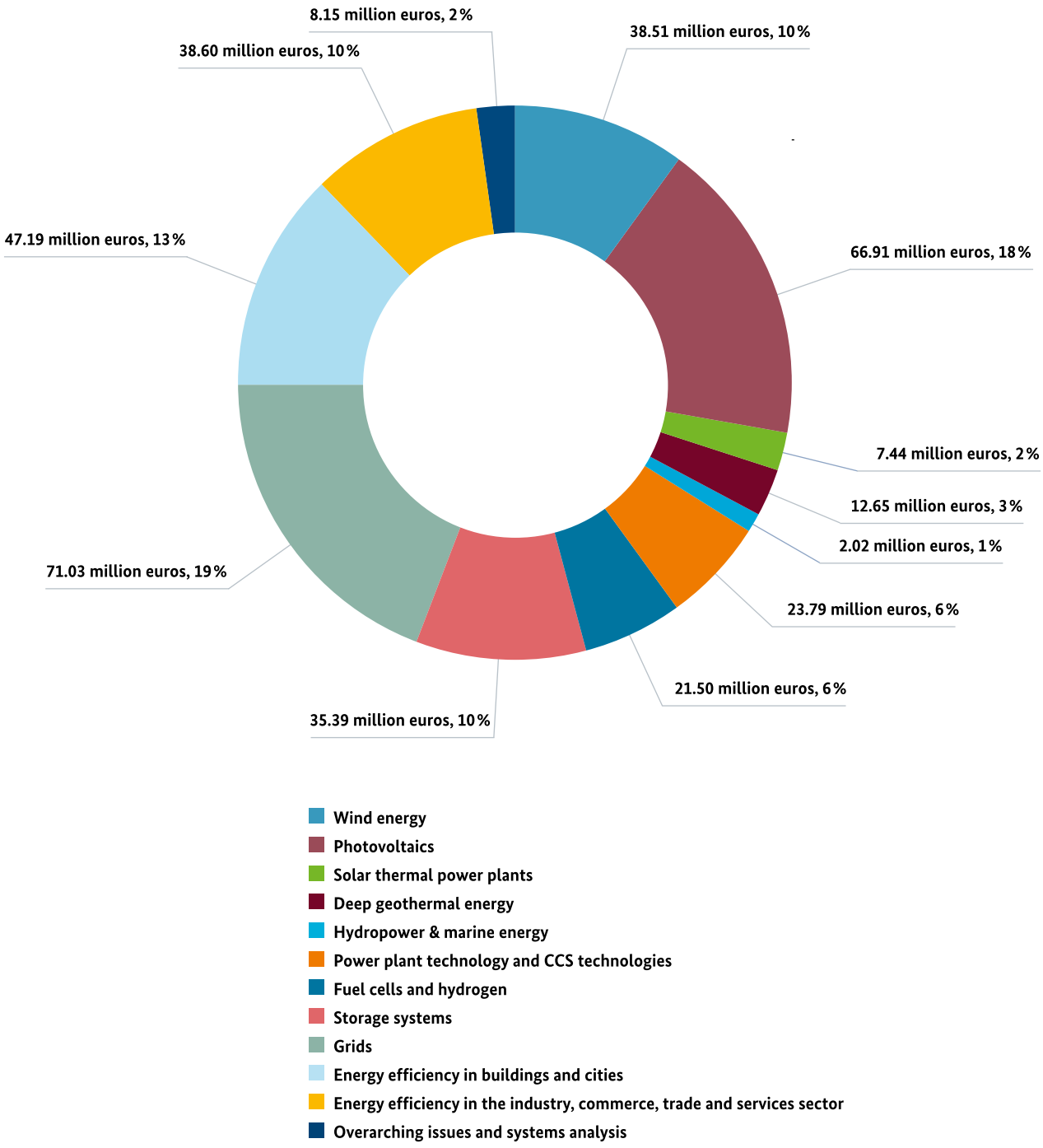
In the area of system-oriented research approaches, the main focus will be placed on combining individual components from different technological areas that have been developed as far as possible into an overall system. The further development and integration of new information and communication technologies, issues of system security and system reliability and public acceptance will all hold positions of central importance here.

European cooperation will be organised under the umbrella of the Strategic Energy Technology Plan (SET-Plan) from the EU Commission. The aim of the SET-Plan is to achieve greater coordination between the various measures undertaken at a national level, as well as between the programmes run by the European Union. In this area, Germany and its partners are utilising the “Berlin Model”

Volume of funding for ongoing projects in 2014



Volume of funding for newly approved projects in 2014



for the targeted and unbureaucratic implementation of European research cooperation.

Cooperating with the federal states in selected areas could help to ensure that different sets of conditions regarding funding complement each other in an ideal way.

The BMWi is currently setting up the central information system EnArgus with the aim of creating greater transparency in state funding policy and enabling the better evaluation of technological development, as well as providing the most comprehensive overview possible of research activities in the area of energy technologies.

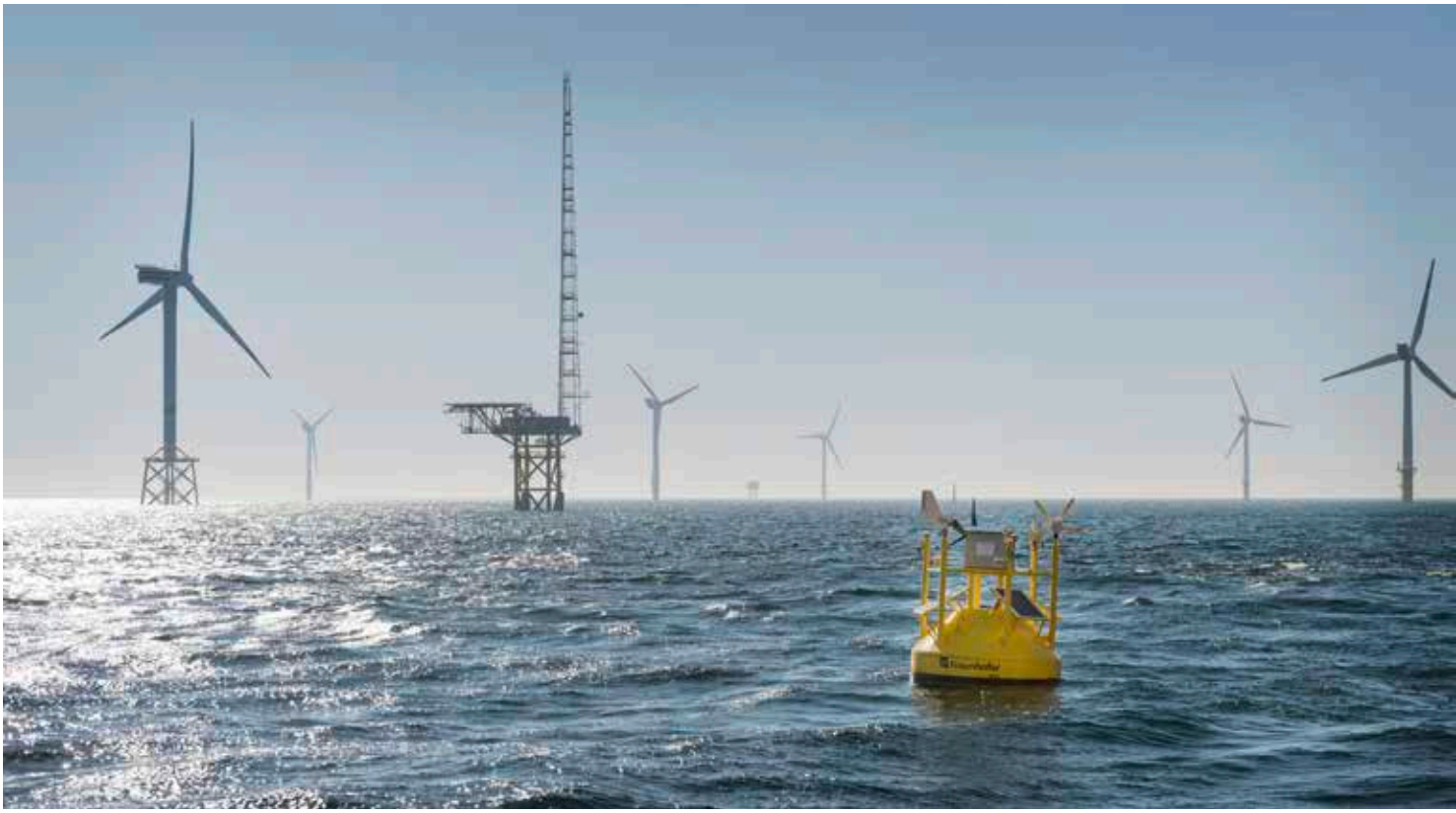
The BMWi is responsible for leading the 6th Energy Research Programme and for funding applied research and technological developments in all energy technologies (except for bioenergy). The work on the Energy Research Programme is supplemented by the Federal Ministry of Education and Research (BMBF), who provide assistance on fundamental issues, and the Federal Ministry of Food and Agriculture (BMEL). BMEL funds the developments in the area of bioenergy.

The basic principles for research funding are described in the 6th Energy Research Programme. This report continues the series of publications titled “Innovation Through Research”. Following the restructuring of energy research, this annual report is the first in the series to cover the entire spectrum of research funding topics supported by the BMWi in the areas of both energy efficiency and also renewable energies.

The research results from 2014 will be presented in detail in this report. They contribute to the superordinate goals of the energy transition as follows:

- Increasing energy efficiency in the conversion, distribution and use of energy (contribution to reducing primary energy consumption and increasing the proportion of electricity generation accounted for by renewable energies)
- Reducing greenhouse gas emissions (contribution to the climate policy goals)
- Reducing the cost of technologies through higher levels of efficiency and optimised production, as well as
- Increasing the international competitiveness of German companies and research institutions and the creation of viable, high quality jobs

Wind energy



The use of onshore wind energy is a central component of the energy transition because it is currently the least expensive technology for generating electricity from renewable energies. Onshore wind energy already makes a major contribution today to electricity generation from renewable energies. There is great potential for the further expansion of wind energy both through the increased utilisation of the wind at sea and also by opening up suitable sites on land, especially using modern, more efficient turbines.

Market developments in Germany and across the world

At 1:30 p.m. on the 12 December 2014 wind turbines fed a total of 29.7 gigawatts of power into the system. The volume of electricity generated over 24 hours on the 22 December 2014 was around 661 gigawatt hours. The electricity generated by conventional power plants on the same day was only slightly higher at 678 gigawatt hours. Both the power fed into the system and the generated volume of electricity were new record values and underline the great importance of wind energy for the achievement of the energy transition in Germany.

In the first half of 2014, the German market for onshore wind turbines grew significantly. In this period, around 650 new wind turbines with a rated power of 1,723 megawatts were erected in Germany. This was around two thirds more than in the same period of the previous year. The trend toward larger turbine outputs and also longer rotor blades is continuing. These higher investment costs can, however, increase the number of full-load hours and significantly increase the feed-in volumes. In addition, it also means that sites where the wind is not as strong can be connected to the system so that the need for the grid to be expanded is reduced. On 31 December 2014, a total of 24,867 wind turbines were operating onshore in Germany with a total installed output of around 38,116 megawatts. Germany has thus achieved the record for newly installed wind turbines: There was more installed output erected in the form of wind turbines in 2014 than ever before in one year. In terms of the proportion of

electricity generation accounted for by onshore wind energy in an average wind year, this represented an increase of up to ten percent at the time.

The expansion of offshore wind energy is also proceeding at pace. On 31 December 2014, a total of 258 offshore wind turbines with a total output of 1,049 megawatts in the German North Sea and Baltic Sea fed electricity into the German energy system. It was thus possible to exceed the significant gigawatt milestone. A total of 142 offshore wind turbines with an output of 528.9 megawatts were added to the grid, which meant that the expansion in this area had thus more than doubled in comparison to the previous year. Alongside the already connected offshore wind turbines, a further 268 with an output of 1,218 megawatts were completely erected in 2014, but were not yet feeding electricity into the grid by the end of the year. The total output of the 285 erected offshore wind turbines that were not yet connected to the grid by the end of 2014 was 1,303 megawatts. In addition, there are a total of 220 foundations laid ready for the further installation of wind turbines.

The result is that there is currently a total output from wind turbines of 3,275 megawatts either under construction, completed or already connected to the grid. This is just over half of the 6,500 megawatts of offshore output envisaged by the German federal government for 2020.

The global market recovered in 2014 after its collapse in 2013. The driving force in this area continues to be Asia, led by China. However, the expansion of wind energy in the USA has moved forward again after it came to a standstill the year before. The newly installed output there was around 1,250 megawatts over the whole of 2014. Other promising markets are South Africa, Brazil, Mexico and India.

It can be expected that the expansion of onshore wind energy in Germany will develop at a stable level in the coming year. The net expansion of 2,500 megawatts per year plus coverage of the capacity of power plants that have been shut down desired by the German federal government offers great potential for innovative products and other increases in efficiency. The expansion of offshore wind energy in 2015 is likely to be at least in line with the second level of expansion envisioned by the German federal government of a further 1,500 megawatts of newly connected output.

German companies, universities and research institutions are amongst the very best in the world in the area of wind energy. Innovations will secure this leading international position. Research supports German manufacturers and service providers by developing solutions for specific requirements in foreign markets. This includes foundation structures for greater depths at sea, as well as rotor blades and concepts for turbines in cold climatic zones or the ecological compatibility of the turbines and their installation processes. This important research is supported by the BMWi through the funding of projects that focus on the development of concepts for foreign markets, whereby the exploitation of the research findings primarily takes place in Germany.

Progress in research and development

Onshore wind energy has already achieved a high degree of maturity and turbines achieve technical availability of over 95 percent. Significant challenges in the further development of these turbines are the technical impacts resulting from increasing rotor blade diameters in combination with relatively small machines and greater hub heights. The Test Center for Support Structures in Hanover was opened in 2014 and and aims to deliver results for the construction of foundation structures by using suitable large-scale test equipment as well as laboratory equipment. In combination with the almost complete nacelle test stands in Aachen (Center for Wind Power Drives – CWD) and Bremerhaven (Dynamic Nacelle Testing Laboratory – DyNaLab) and the existing capacities for testing rotor blades, it will be possible to carry out substantial analyses and development steps under controlled conditions.

In the offshore sector, it has been possible to develop measures for the mitigation of noise during the installation of offshore wind turbine foundations down to a water depth of 25 metres thanks to intensive research and development activities. Technologies such as the “Big Bubble Curtain”, the use of cladding tubes or so-called hydro sound dampers enable noise emission limits set by legislators to be observed when erecting offshore wind turbines, for example in the Butendiek wind farm. Because these innovative technologies reduce the range of disturbances for marine mammals by up to 90 percent, they make a significant contribution to the protection of species in the German exclusive economic zone. At the

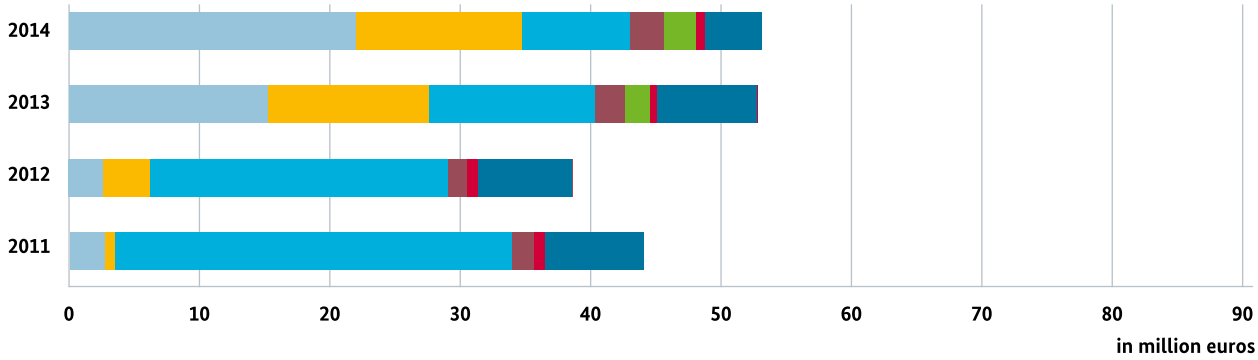
same time, other intensive research activities in the area of new low noise foundation technologies, such as suction buckets or vibration piling methods, will continue to be initiated to further develop the environmentally friendly expansion of offshore wind energy.

Strategy for research funding

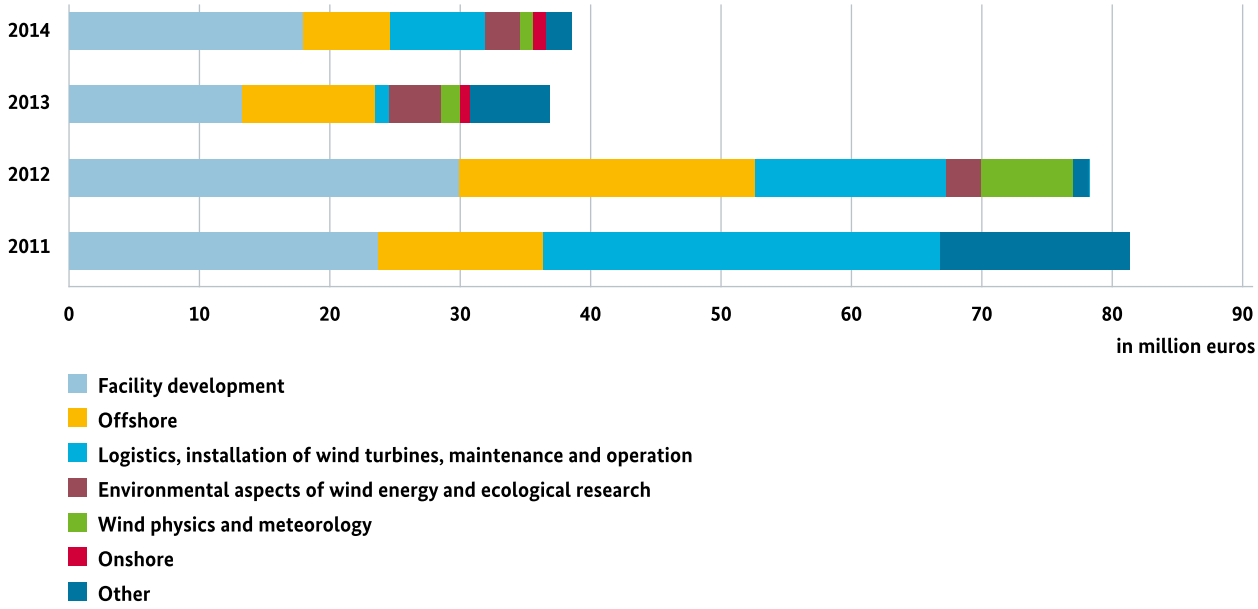
The use of wind energy in Germany can make the largest and most economical contribution to increasing the proportion of electricity production accounted for by renewable energies. Therefore, the research funding provided by the BMWi in the area of wind energy particularly focuses on achieving reductions in costs. Increasing the yields and reliable operation of the wind turbines are two factors that will also be decisive for reducing specific costs.

Due to the further growth in output from wind turbines, the weight and size of the machines are taking a leading role when it comes to cost because the cost to install a wind turbine accounts for a considerable proportion of the overall costs. New concepts for reduced mass and

Wind energy: Distribution of funding between 2011 and 2014



Wind energy: Trend in the volume of newly approved funding since 2011



resource efficient drive trains are being investigated in projects such as Magnetring II. Here, a large-scale gearless ring generator with an output of 10 megawatts is being developed, which should have clear advantages in terms of weight compared to existing concepts.

In order to make electricity generation from wind energy more predictable and stable, it is also necessary to gain a better understanding of wind as a natural resource and hence utilise it more effectively. On the one hand, an improved method to forecast wind yields in complex regions such as mountainous terrain or forests is being investigated, while on the other hand, improved methods to simulate wind loads for the design of layouts for wind turbines are being developed. In addition, research is being conducted into new concepts for regulating wind turbines and wind farms to optimise the energy yield.

Methods that can intelligently and predictively monitor the status and load should be designed to avoid damage and extreme loads with the help of suitable technologies and control concepts. This will make it possible to further increase the reliability of wind turbines. The use of a new nacelle test rig will also help to achieve the same objective by subjecting drive trains in wind turbines to realistic, accelerated load tests. In the FVA-Gondel project (research consortium for drive technology in nacelles), a diverse range of loads is being tested on the drive trains of turbines. The results will lead to the targeted improvement of models for the development of wind turbines and aid the understanding of damage mechanisms in wind turbines and their components.

The integration of the generated electricity into the public supply grids is of decisive importance for the further expansion of wind energy. Relevant research topics thus include issues relating to connecting offshore wind farms to the grid, load and generation management systems, wind energy-specific storage and the improvement of wind forecasting.

In the area of onshore wind energy, the subject of public acceptance is especially important, particularly in view of the ambitious expansion strategy.

In contrast, the focus in the area of offshore wind energy will be placed on achieving further significant cost reductions in the installation, logistics, operation and maintenance of turbines and minimising their ecological impact. New types of low noise foundation concepts such as suction bucket or gravity foundations are important here both from a cost perspective and also from an ecological standpoint. Another significant cost driver in the area of offshore turbines is the high cost of operating and maintaining the wind farms because this is only possible on the high seas at great expense and in narrow time frames. Professional software tools for optimising the planning for wind turbine operation with respect to cost and risk, which will bring together existing knowledge, should help resolve issues in this area.

Current ecological research associated with wind energy is primarily investigating the impact of wind turbines on birds. The latest findings will be presented to the authorities and will be used directly in the approval process. This will give operators planning security and support the environmentally friendly expansion of wind energy (see page 21-23).

In the area of wind energy, the BMWi approved new funding for a total of 63 projects with a funding volume of around 38.5 million euros (2013: 36.8 million euros). Ongoing research projects were provided with about the same high level of funding as in the previous year with around 53 million euros (2013: 52.6 million euros).

SPECIAL TOPIC

Automated rotor blade production: Driving quality up and costs down

Rotor blades account for around a fifth of the overall costs of wind turbines. They are currently almost exclusively manufactured by hand. Research and industry are investigating areas where automation would be cost effective and how rotor blades could be devised for this purpose.

What opportunities does the automated production of rotor blades offer?

Sayer: In the face of international competition, rotor blade manufacturers face the challenge of reducing costs and at the same time increasing the quantities manufactured. We want to tackle this by increasingly industrialising the process chain. We assume that production costs can be reduced by ten percent through industrialised manufacturing, as well as through savings made in personnel and materials.
This industrialisation will, however, not only be carried out for cost reasons. Equally important is improving the quality of the rotor blades. In processes that require a reproducibly high level of precision, automation can avoid rectification steps and improve quality. This prolongs the lifespan of the rotor blades and avoids unnecessary repairs.
And in the case of very large rotor blades, there is also a third driver: the manufacturability itself. For example, workers have to rely on special aids to fit materials in the roots of very large rotor blades. When blade lengths reach 80 metres, the working conditions become ever more difficult. Specially developed machines would be able to do this more safely and reliably.

How are you proceeding in concrete terms?

Sayer: In the BladeMaker project, a consortium consisting of participants from industry and research is developing concepts and technologies for industrialised rotor blade production. We are investigating the entire manufacturing chain for the production of rotor blades and calculating the economic potential. A large number of technological approaches that tackle different production steps form the starting point for this work: starting with the construction of the moulds, fibre placement and handling individual components through to post-production work on the finished blank rotor blades.
The next step is to define the processes, then source the hardware for automating these processes and develop the necessary process technology.
In order to be able to test the technology practically, we are developing reference rotor blades.
We want to conduct the central development work and tests in the planned BladeMaker demonstration centre for the industrialised production of rotor blades. Manufacturers will be able to use the assembly line at the centre for their own rotor blade models and thus determine the savings potential and even develop new technologies.

Is the full automation of rotor blade production conceivable?

Sayer: Yes, it is technically conceivable. However, I do not believe that it is currently economically feasible because not all of the processes are suited to automation. For example, applying the skin to the rotor blades requires a comparatively high level of investment but promises only minor savings. Ultimately, the economic viability is also dependent on the relevant planning basis: In the case of a large production volume of 3,000 rotor blades per year, the economic basis and resulting concepts critical to the consideration of industrialised production are certainly different than for a production volume of 300 rotor blades – and other production processes also come into question. It is probable that manufacturers will start with partial automation and then convert the various processes step by step. In order to significantly improve economic efficiency, we are developing and researching into less expensive automation solutions and materials with the same levels of quality and robustness from rotor blades.

Dr. Florian Sayer, Head of Rotor Blades at the Fraunhofer IWES

Alongside automation, you also have the goal of developing so-called "smart blades". Are these two developments in any way compatible?

Sayer: In terms of the technologies used for smart blades, it is important to differentiate between passive and active technologies. Industrialisation is beneficial for passive technologies, such as rotor blades with geometric and structural bending-torsion couplings: I have better control here over the individual process steps and can improve the quality. The more reliable the production processes, the earlier I can fully exploit these types of smart technologies. The cost-benefit analysis for active technologies, such as active trailing edges, is still ongoing. However, it is also clear here that industrialised production of the rotor blades will help to achieve greater reliability and quality.

SPECIAL TOPIC

Two concepts – two opinions: with or without a gearbox?

There have been two fundamental construction methods for wind turbines for a number of years: turbines with and turbines without a gearbox. Both are available on the market and the performance, reliability and lifespan of both options is being continuously advanced. Professor Dr. Friedrich Klinger is a pioneer in the area of wind turbines without gearboxes: He has been working on this concept since 1990 with his wind energy research group, which is today based at the Saar University of Applied Sciences (HTW). In contrast, the research work carried out by Professor Dr. Georg Jacobs, Head of the Institute for Machine Elements and Machine Design at RWTH Aachen, specialises in the further development of wind turbines with gearboxes. Both of these academics have briefly presented the benefits of each concept for the BMWi annual research report.

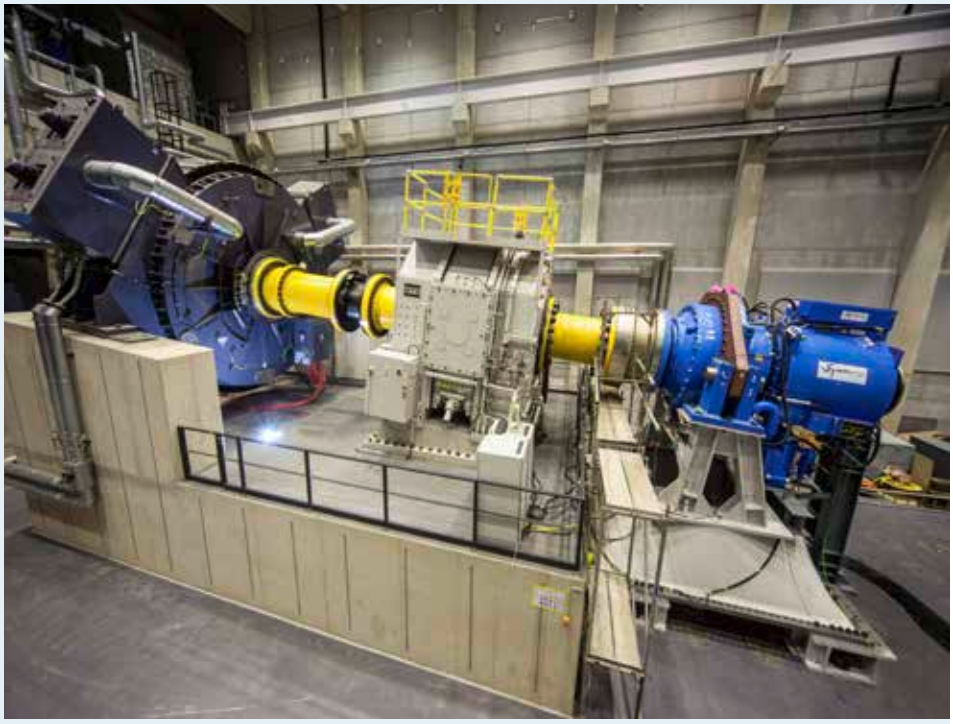
Professor Dr. Friedrich Klinger and his sketch of a wind turbine without a gearbox

What, in your opinion, are the technical advantages of wind turbines without a gearbox?
Klinger: The advantage is that the power from the rotor is directly transferred to the generator, which is why we also call this concept direct drive. The gearbox between the rotor and the generator is omitted. This means that the drive train, at least down to the inverter, is almost maintenance-free. The turbine is thus more robust, the layout more simple and the number of parts reduced by more than half. In the lower partial-load range, up to approximately 30 percent of the nominal output, the transmission efficiency is significantly better. This is due to the fact that permanent magnets are used for the synchronous generator so that the normal loss in performance when using electromagnets is not experienced. Our institute was the first to propose and realise this type of design for generators in wind turbines and we were able to position the rotor on the outside. The external diameter of the generator is thus smaller.

What further developments are possible here for example?
Klinger: There are proposals to construct the generator with superconducting coils to reduce its size. However, the costs for their development and manufacture are possibly too high. A purely hydrostatic drive train has been developed and built by Artemis Intelligent Power Ltd. and Mitsubishi Hitachi Power Systems Ltd. The gearbox and inverter are replaced here by oil-hydraulic pumps and motors that make variable speed transmission possible. A further development of the gearless drive train that we are currently working on is the hub generator. It is an attempt to install the generator in the hub or to build the rotor blades directly onto the external rotor of the generator. The aim here is to lower the weight and dispense with the connecting flange.

Will this drive train technology establish itself as the dominant technology on the market in the next ten to twenty years?
Klinger: As the availability and maintenance costs for large megawatt turbines will play an ever more important role in electricity generation costs, direct drive wind turbines will become more established in the long term, predominantly at least. Even in the case of mass-market products like the bicycle dynamo, it took decades until friction gear dynamos were for the most part replaced by direct drive hub dynamos.

Professor Dr. Georg Jacobs



System test stand for a 4 megawatt wind turbine at RWTH Aachen from the Ziel2 project "Improving the operating behaviour of onshore wind turbines with the aid of a new system test stand"

What, in your opinion, are the technical advantages of wind turbines with a gearbox?

Jacobs: The rotor of a wind turbine harvests around 50 percent of the power from the flow of the wind and converts it into mechanical and then electrical energy with the help of a generator. The size of the required generator is primarily dependent on its rotational speed. The lower the speed, the larger it needs to be and thus the more costly the necessary copper and magnetic materials will be. Gearboxes make it possible to boost the low rotational speed of the rotor that is restricted by the physical construction of the wind turbine and thus effectively reduce the size of the generator. Using a modern 2.5 megawatt class onshore wind turbine as an example, it is possible to boost the rotational speed of the rotor from approximately 14 revolutions per minute up to a generator speed of 500-1650 revolutions per minute.

The use of gearboxes is prevalent in many areas of application for industrial drive technology in order to reduce the size of generators, pumps and electrical and hydraulic motors, as well as to save costs. Large manufacturers of drive components for electric vehicles also consistently utilise the cost benefits of high-speed electric motors in combination with mechanical gearboxes.

As cost pressures – particularly in the area of onshore wind turbines – are increasing due to international competition, manufacturers are increasingly attempting to transfer those cost benefits that have become established in other sectors to their own products.

What further developments are possible here for example?

Jacobs: A prerequisite for the development described above is a further increase in the reliability of gearboxes in wind turbines. The reliability of wind turbines is currently decisively influenced by the performance of the bearings – not only those in the gearbox but also the main bearings for the rotor itself. In order to make progress here, it is necessary to analyse the operating conditions, particularly the local loads acting on the wind turbines, and take these into account sufficiently when developing and testing roller bearings.

Will this drive train technology establish itself as the dominant technology on the market in the next ten to twenty years?

Jacobs: Yes, because it is expected that these improvements in reliability will be successfully achieved.

HIGHLIGHT

Opening of a test centre for support structures that is unique in Europe

Testing loads like those experienced on the high seas is now possible at a new test centre for foundations and supporting structures for wind turbines. The test rig at the new large-scale facility in Hanover is unique in Europe.

Wind turbines are becoming increasingly larger and more powerful. This also means that the loads placed on the individual components in the turbines are also higher. Especially in offshore sites, the foundations and supporting structures need to withstand extreme stresses: Gusts of wind tugging at the rotors, waves crashing against the supporting structures and marine currents surging continuously around the foundations of the wind turbine.

Until now these loads had to be tested far from the coast in deep waters. However, it has been possible to test the supporting structures and foundations for turbines in a laboratory since autumn 2014. In the new Test Center for Support Structures (TTH) in Hanover, realistic large-scale experiments can be carried out. This reduces the costs for exploiting wind energy because companies can quickly transfer the test results into practice.

Scientists are investigating the technical reliability of the structures through realistic simulations of the conditions at sea. The test hall is 20 metres high and not only contains laboratories and workshops but above all two large-scale testing facilities that are unique in Europe. In the foundation test pit, the scientists investigate the stability of foundations for wind turbines. The supporting structures are installed in a ten metres deep tank. It is filled with water and water-saturated sandy subsoil which represents the seabed. Hydraulic cylinders continuously subject the supporting structures to tensile and compressive forces. This enables the scientists to investigate how the supporting structure and the subsoil around the supporting structure behave when subjected to continuous cyclical loads – such as those exerted by marine currents.

In the second test stand, the so-called “Span”, the researchers test individual components of supporting structures, such as the grouted joints. These tube-in-tube connections couple the foundations with the supporting structure in offshore wind turbines. Solid fine grain grout fills the cavities between the inner and outer tubes. In the TTH, the scientists exert tension on these components in a 18.5 metre long and 10 metre wide multiaxial test stand. They can thus investigate whether the grout will crumble due to the cyclical load and the inner tube will slip.

These realistic tests provide manufacturers, project planners and operators with important information on the stresses faced by supporting structures and about their lifespans. Construction processes can thus be optimised and innovative supporting structure designs can be brought to the market more quickly and more cost effectively.

The TTH is operated by the Leibniz Universität Hannover and is used by the Fraunhofer Institute for Wind Energy and Energy System Technology IWES as a partner and the Center for Wind Energy Research (ForWind) – a consortium of the universities of Hanover, Oldenburg and Bremen – to carry out their research projects.

The BMWi provided funding of 17.8 million euros for the construction and commissioning of the Test Center.

The Test Center has two large-scale testing facilities that are unique in Europe for testing the supporting structures of wind turbines: In the foundation test pit (at the front of the picture), experiments can be carried out on supporting structures installed in the water and pile driving processes. The “Span” (at the back of the picture) is used to clamp large-scale supporting structures in place so that their fatigue behaviour can be investigated under multiaxial loads

Realistic flow simulations are decisive for evaluating sites and the optimal planning of future offshore wind farms

Selected funded projects

Better assessment of sites

Potentially interesting sites are initially assessed for their suitability before the construction of wind turbines and wind farms. Wind measurement masts are erected to measure the local wind conditions in order to develop reliable yield forecasts. This measurement campaign lasts at least one year and delays the construction date, which is time-consuming and cost-intensive. The growing complexity of potential sites also increases the need for a precise and efficient evaluation of the surrounding terrain.

In the **AssiSt** (turbine flow simulations and site calibration) joint project, the aim is to develop a realistic flow simulation of the entire wind turbine under a diverse range of local conditions. For this purpose, the researchers calibrate the turbulence models used in the FLOWer and THETA software tools to the individual sites. The simulations should be run with wind flow conditions that are as realistic as possible – which are sourced with the help of the meteorological simulation programme PALM. The forecasts use measurement data in order to make a reliable, inexpensive and quick assessment of a site. Achieving greater accuracy in these forecasts makes it possible to reduce costly measurement processes. This accelerates the planning process and minimises site-specific yield risk.

The simulations are not only designed for assessing potential sites but also to deliver realistic data for optimally planning the layout of the wind farm. In addition, researchers want to improve the design of the nacelle and investigate the influence a sudden changeover from a simple stratified wind flow to a chaotic-turbulent wind flow has aerodynamically on the rotor blades of a wind turbine. They hope to achieve further improvements in performance with this work.

The joint project is coordinated by WRD Wobben Research & Development GmbH, the construction and development department of the wind turbine manufacturer ENERCON. Project partners include the University of Stuttgart, the Leibniz Universität Hannover and the German Aerospace Centre (DLR).

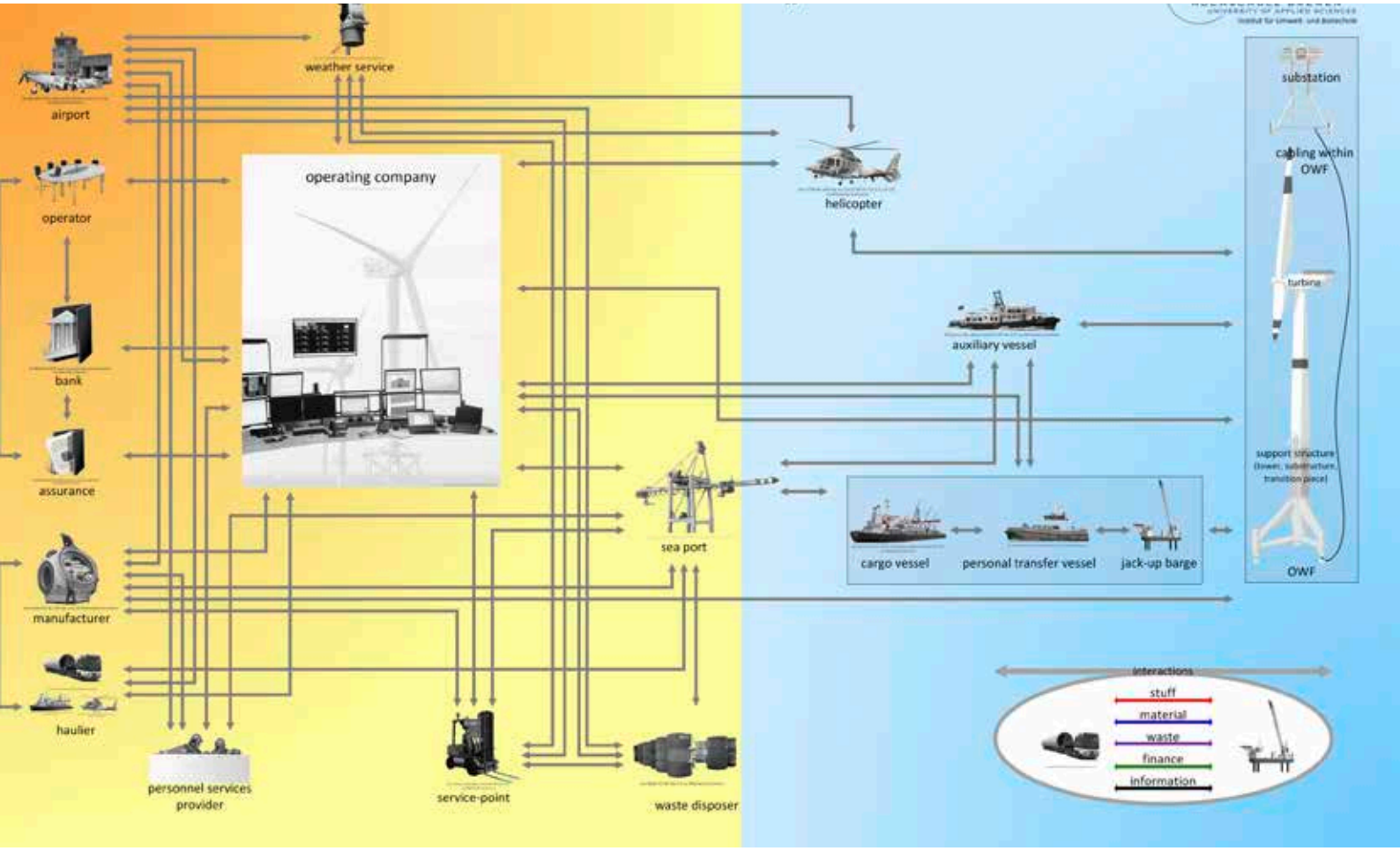
The BMWi is funding AssiSt with around 1.3 million euros.

Optimising the operation of offshore wind farms

Alongside the technical requirements that an offshore wind farm has to fulfil, efficient operating and maintenance processes are a prerequisite for a reliable and economically viable overall system.

The offshore wind farm as a performance system contains many different processes. In the **SystOp Offshore Wind** project, the different components and interfaces, as well as the material, personnel and information flows and their interactions, are recorded and analysed. The aim of the project is the further development and optimisation of the offshore wind farm performance system using standardised measures and strategies.

Extract from the offshore wind farm performance system



Through structured maintenance processes, the researchers can identify critical processes and interfaces in the operation of the offshore wind farm based on a risk analysis and with the help of a simulation tool. Using a risk analysis method adapted to offshore wind power, the wind farm operators can analyse potential defects in the process cycle and receive information on the risk of delays and the need for additional resources. At the same time, the simulation tool enables them to compare the different alternative processes for resolving problems with one another. The results will be described in the German Offshore Wind Operation Guide (GOWOG).

In addition, the scientists have developed the *German Wind Power Plant Model (GWPPM)* as a reference model. This model describes processes that can occur during the lifecycle of an offshore wind farm and provides important information to wind farm operators for standardising complex procedures when operating wind farms on the high seas.

This planning and optimisation tool uses standardised quality assurance methods. Operators, project planners, investors and insurers can thus efficiently and reliably develop, plan and evaluate maintenance processes for offshore wind farms. This will increase the availability and thus the economic efficiency of offshore wind energy. SystOp Offshore Wind is a joint project run by the University of Bremen together with the IZP Dresden mbH, the University of Hamburg and BTC Business Technology Consulting AG. The BMWi funded the project with around 750,000 euros.

In a subsequent project called **KrOW!**, the joint partners together with EWE AG (operator of wind farms) are investigating the costs and the risk-managed operation of offshore wind farms. The researchers want to develop a simulation tool for strategic and operational management. This tool will also take into account quality and environmental management aspects. In addition, the aim is to also design

a training tool for decision makers and operating personnel. The researchers are validating all methods during the ongoing operation of an offshore wind farm. The BMWi is funding KrOW! with around 1.4 million euros.

Sustainable prevention of gear damage

Wind turbines must be able to withstand high dynamic loads. But in recent years a growing number of turbines are suffering from damage to the bearings and gears. One reason for this damage could be defects in the quality of the gear components. Reliable and informative measurement technology should make it possible to sustainably prevent this type of damage in the future.

The aim of the **EVeQT** research project is to increase the availability and optimise the quality of drive train components and gears for wind turbines, as well as to reduce specific costs as a result. Under the coordination of the University of Bremen, the project partners want to make it possible to take reliable measurements for large gears in wind turbines and to achieve this in the production of new gearwheels, the provision of spare parts and also during later operation. In a similar way to what was done for highly developed gears in the automobile industry, the consortium thus want to exploit the technological and economic potential for innovations in this area.

The project partners are developing a completely traceable process chain as the basis for delivering reliable measurements. This process chain begins with the Physical Technical Federal Institution (PTB), incorporates accredited laboratories and stretches through to industry. Amongst other things, the scientists are developing new standards for large gears that are adapted to the requirements of industry. They aim to thus create the prerequisites for future assessment bodies for accrediting the conformity of large gears. The University of Bremen (BIMAQ) plans to establish a laboratory for large gears as a certified accreditation body in Germany. Industry would then be able to have their large gears and gear measurement standards calibrated for the first time and thus prove that the quality of their gear measurements conforms with these standards.

The project partners include the University of Bremen, Hexagon Metrology GmbH and the PTB. The BMWi is funding EVeQT with around 2.3 million euros.

A workpiece-like large gear measurement standard developed by the PTB in the EVeQT project

HIGHLIGHT

Innovative structure for the foundations of offshore wind farms

Currently, offshore wind turbines are primarily erected on foundations that are anchored to the seabed with the help of the pile driving process. The installation has negative effect on the marine environment due to the high water-borne noise emissions.

An interesting alternative to hammered piles is offered by suction bucket foundations. This solution consists of one or more steel cylinders (buckets) that are open at the bottom and are fixed to the underneath of the supporting structure. The steel cylinder is then placed onto the seabed and suction pumps are used to create negative pressure, whereby the steel cylinder is progressively sucked into the seabed. The advantage of this innovative solution is that the foundation is installed in one single lifting and installation process so that both the construction time and also the associated costs are reduced. In addition, it also protects sensitive marine ecosystems because no noise-intensive work is required.

The prototype for a suction bucket jacket foundation was successfully installed in the Borkum Riffgrund 1 wind farm in the German North Sea by project developers DONG Energy in autumn 2014. The erection and testing of the prototype was supported by the Offshore Wind Accelerator funding initiative from Carbon Trust, a non-profit organisation based in Great Britain.

The BMWi funded **Monitoring Suction Bucket Jacket** joint project will link up with this field test. The Leibniz Universität Hannover, the Federal Institute for Materials Research and Testing (BAM) and DONG Energy Renewables Germany GmbH have joined forces to work together on this project. Comprehensive measurement data will be collected during the prototype test that will be used to validate and further develop already existing calculation methods and models for the measurement and installation of suction bucket foundations. On the basis of the validated models, the aim is to optimise the structure and design of these suction bucket foundations and make them eligible for certification and approval in the medium to long term. It is expected that the foundation costs could be reduced by 15 to 20 percent using this new concept. The entire offshore wind industry would benefit from this development.

The BMWi is funding the joint project “Monitoring SBJ” with around 1.1 million euros.

Prototype of a design for a suction bucket jacket

Building offshore wind farms in an environmentally compatible way

In the **HELBIRD** project, Kiel University is investigating the possible impact of offshore wind farms on sea birds and marine mammals. The researchers are examining here the German exclusive economic zone (AWZ) north of Heligoland. A number of offshore wind farms with undeveloped corridors between them have been erected in this area since 2012. For the first time, it can now be evaluated whether animals are using the corridors, and if they are, how wide these corridors should be in future wind farm clusters. The direct proximity to the island of Heligoland, where many of the sea bird species in the region breed, makes this area especially suitable for the research.

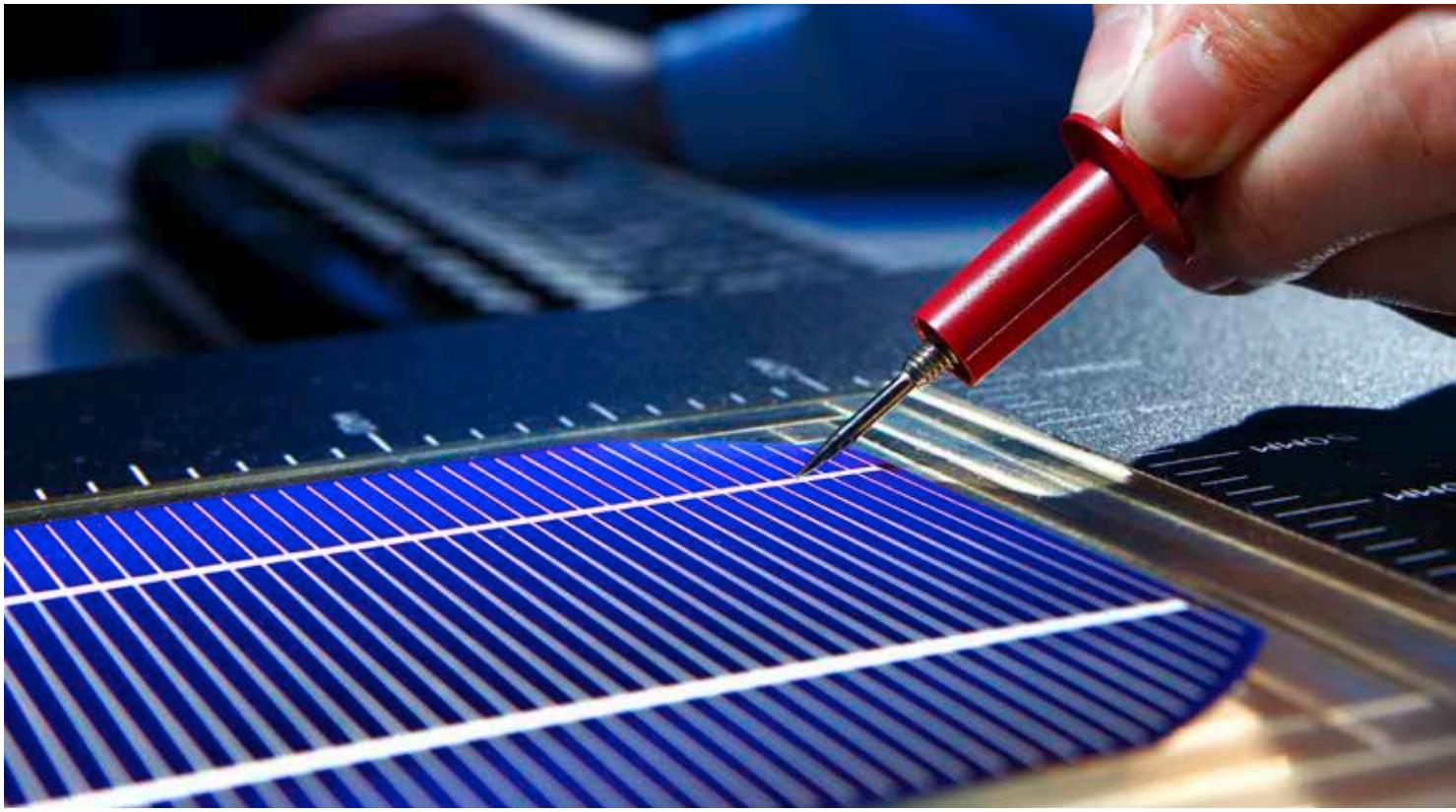
The scientists are recording the distribution patterns and flight heights of the sea birds using recording methods in aircraft with high resolution video and digital cameras. On the basis of this data, they will be able to quantify the possible effects of wind turbines for attracting or repelling sea birds and marine mammals. The researchers want to evaluate and methodologically develop the different recording methods.

Furthermore, the scientists want to utilise GPS data loggers to investigate the behavioural patterns, flight patterns and the use of space of multiple bird species that breed on Heligoland by studying individuals as well as colonies. In the process, they can call on the results of already completed telemetric studies of lesser black-backed gulls and northern gannets. A comparison with the situation before the construction of the offshore wind farms is thus possible.

The project will also contribute to a better understanding, evaluation and classification of the possible environmental impact on sea birds and marine mammals caused by offshore wind farms. The latest findings will be presented to the authorities and will be used directly in the approval process. This will give operators planning security and support the environmentally friendly expansion of wind energy.

The BMWi is funding HELBIRD with around 1.3 million euros. ■

Solar energy



In Germany, solar electricity is often equated with photovoltaics. This technology is easy to use in Germany and an attractive proposition for many homeowners thanks to the funding offered by the Renewable Energy Sources Act (EEG). Alongside photovoltaics, it is also important, however, to mention solar thermal power generation. This energy source cannot be used in Germany because it works using concentrated solar radiation. It thus requires a climate with high direct irradiance as found in Southern Europe, North Africa or also the USA. Therefore, solar thermal power plants are developed in Germany exclusively for export to these countries.

Photovoltaics

It is anticipated that photovoltaics together with wind energy will bear the main burden of Germany's energy supply in the future. They already accounted for around 5.8 percent of German electricity consumption in 2014.

Market developments in Germany and across the world

After 2013 proved as expected to be a difficult year for the photovoltaic industry, a slight upturn was recognisable in 2014. Although production from the installations in Germany remained significantly below expectations at 1.95 gigawatts, the global market grew according to initial forecasts by 40 to 42 gigawatts in 2014 (2013: 37 gigawatts). In Europe, Great Britain was the key player on the market, while China, Japan and the USA were important globally. Global growth also provides German companies with opportunities as long as they are able to offer high-quality products and competitive prices.

In Germany, another large company is now active in the production of solar cells and solar modules for the mass market. After restructuring, the SolarWorld group acquired the production facilities operated by the Solar Energy business unit of Bosch and now has a production capacity of around one gigawatt per year. The company Q-Cells, part of the Hanwha Group from Korea, closed its production facilities in Germany on the first of March 2015. However, it plans to continue its research and development activities.

German plant engineering and construction is well positioned with currently more than 50 companies who were able to increase their sales in 2014.

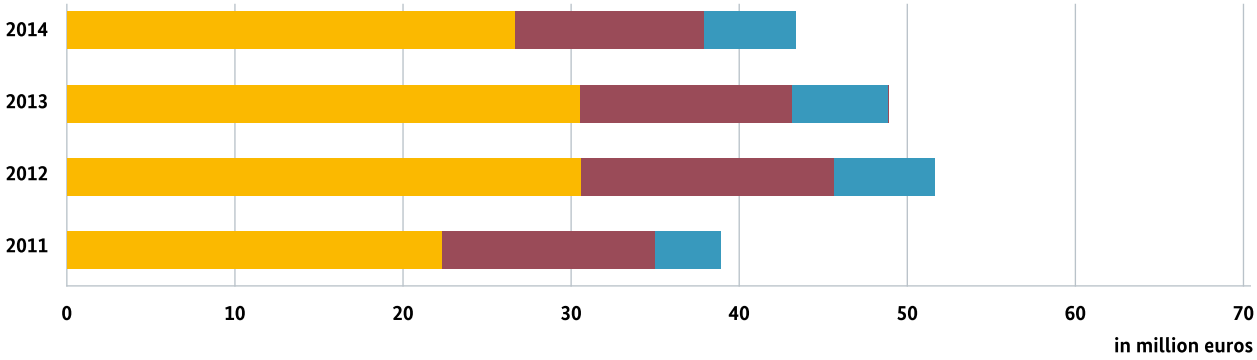
Progress in research and development

It still remains essential to continue reducing the costs of photovoltaic power plants. And there is no alternative here except to develop solar modules that are more efficient – meaning they must generate as much electricity as possible from any sunlight that is available.

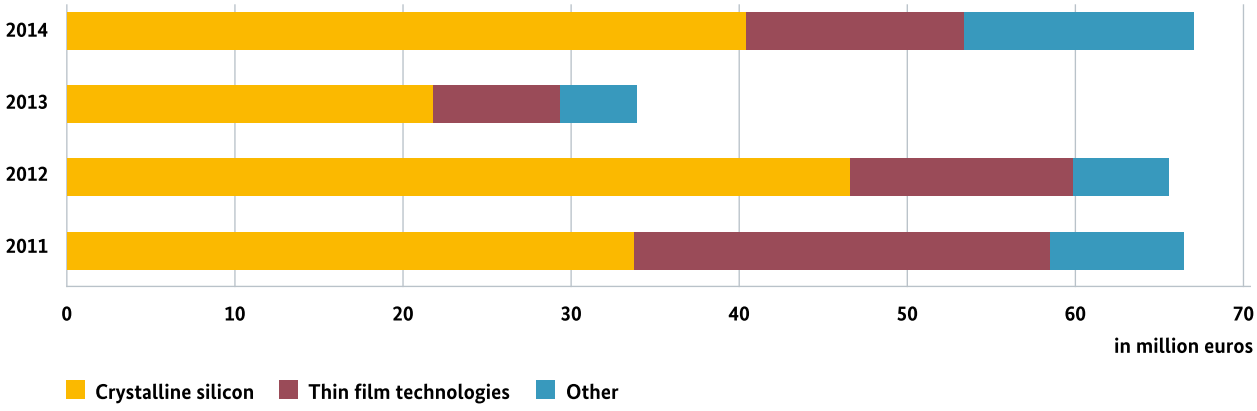
Photovoltaic modules based on crystalline silicon continue to represent the standard on the market. PERC (Passivated Emitter and Rear Contact) technology – where the rear side of the crystalline silicon cell that is shaded from the sun has been further developed – is currently establishing itself in industrial manufacturing. It achieves solar cell efficiency of 20 percent, compared to 18 percent in conventional technology. Even more sophisticated concepts are also in development. The important factor is to transfer these concepts to systems that are suitable for industrial use.

In the area of thin film technologies, it has also been proved in the laboratory that efficiency levels of over 20 percent can be achieved using a semiconductor material made of chemical compounds containing various elements. In Germany, research is concentrating on so-called "CIGS technology". The ZSW Baden-Württemburg (Center for Solar Energy and Hydrogen Research) was once again able to break the world record for the efficiency of these

Photovoltaics: Distribution of funding between 2011 and 2014



Photovoltaics: Trend in the volume of newly approved funding since 2011



types of solar cells in 2014 – the record now stands at 21.7 percent. The task is to now transfer this level to industrial production.

It has not yet been possible to achieve efficiency levels of over 10 percent in products produced using thin-film silicon technology. As a result, the development of this technology in Europe has virtually come to a standstill.

Another world record was announced for concentrator photovoltaics (CPV) in 2014. This technology uses special lenses to concentrate the sunlight onto high-quality solar cells. The Fraunhofer Institute for Solar Energy Systems ISE was able, together with their French partners, to develop a multi-junction cell with an efficiency level of 46 percent.

Strategy for research funding

The goal of the funding provided by the BMWi is to support the German photovoltaic industry, plant construction companies and supplier companies in the development of innovative, competitive solutions and thus make an important contribution to the success of the German energy transition. Joint projects between research facilities and industry – which are managed by industry – are thus the favoured option. An important player here was the "Innovationsallianz Photovoltaik" which was implemented jointly by the BMWi and the BMBF. The success of this strategy has been demonstrated by a series of positive results. The BMWi and the BMBF thus implemented the "Forschung und Entwicklung für Photovoltaik" initiative in 2014. The BMWi provided a total of 43 million euros to 9 industry-led joint projects as part of this initiative.

At the same time, the funding should also support high-quality basic research. The aim here is to enable outstanding German research institutions to provide industry with ideas in the medium term that have already successfully completed the proof-of-concept phase.

Due to the potential for development in German industry described above, funding is being awarded, in particular, to technologies using crystalline silicon, but also to CIGS thin-film technology, concentrator photovoltaics and system technology. This also includes participation in the European SOLAR-ERA.NET (European Research Area).

Around 43.3 million euros was issued to ongoing projects in the area of photovoltaics in 2014, which represented a slight fall compared to the previous year (2013: 48.7 million euros). At the same time, the funding provided to newly approved projects almost doubled. In total, the BMWi approved new funding in the area of photovoltaics for 90 projects in 2014 with a total volume of around 66.9 million euros (2013: around 34 million euros) – which also includes those projects within the new funding initiative.

Selected funded projects

Less diesel and more photovoltaics for island grid systems

Self-sufficient electricity systems independent of the integrated grid – so-called island grid systems – still mainly work using diesel generators. This global market, with a current scope of around 20 gigawatts per year, is now set to be supplemented or replaced by sustainable energy supply systems. The **PV Diesel** project primarily focuses on the use of photovoltaics (PV) for this purpose, which, together with diesel generators, offer a suitable inexpensive and reliable alternative in system solutions. SMA Solar Technology AG (as the coordinator), the Märkisches Werk GmbH (MWH), the Fraunhofer Institute for Wind Energy and Energy System Technology IWES, the Fraunhofer Institute for Solar Energy Systems ISE and the Cologne University of Applied Sciences are together working first and foremost on large island grid systems in the multi-megawatt range that consist of multiple diesel generators and PV power plants. System technology is the main focus of this work.

The project partners are developing, amongst other things, a specially adapted, voltage regulated, megawatt class battery inverter for use in PV/diesel island grid systems, which can be combined with different battery technologies, and a special PV/diesel hybrid controller that optimises the interplay between the battery inverter, PV inverter and diesel generator as the central control unit. There have not yet been any suitable series-production system solutions for this performance class available on the market, which has meant that the diesel generator has to operate around the clock to maintain the grid, meaning that solar energy can only contribute a small proportion of the power. The pro-

PV/diesel systems with PV, battery storage and diesel generators for the independent supply of a small off-grid facility (in this case a mine)

ject aims to optimise the island grid system as a whole, making it reliable and economic to use so that the proportion of the generated electricity accounted for by solar energy can be significantly increased. Due to the intended modular construction, it should be possible to flexibly adapt these systems to a diverse range of applications. The diesel consumption in these types of modern PV/diesel system is significantly reduced overall in comparison to current solutions. This reduces operating costs and preserves the environment. The BMWi is funding this project as part of the funding announcement "R&D for Photovoltaics" with around 2.3 million euros.

Highly efficient modules for economic photovoltaic electricity

Three complementary approaches for reducing the electricity generation costs for crystalline silicon modules are being combined in the **LAURA** project: the development of highly efficient modules, cheaper battery storage and intelligent energy management systems.

The project partners under the coordination of SolarWorld Innovations GmbH and including the Federal Institute for Materials Research and Testing, the Mittweida University of Applied Sciences, MBJ Solutions GmbH, Humboldt-Universität zu Berlin, the Fraunhofer Center for Silicon Photovoltaics CSP and the HTW University of Applied Sciences Berlin are working on the development of innovative module concepts with low electrical and optical losses, as well as improved quality. The work aims to develop a new method for interconnecting the solar cells. In addition, the light should be better coupled and captured within the module. Alongside these enhancements to the solar cells, the aim is to develop photovoltaic modules with improved performance of over ten percent compared to current levels by the end of the project.

Another focus of the project is to improve the quality of the modules. In this area, the project partners are working, in particular, on improved optics, a longer lifespan, better resistance to the influence of the weather through improved material properties and reduced module degradation. This will require the development of faster quality testing to speed up the development cycle. Due to the improved performance and quality of the modules, it should be possible to significantly reduce the electricity generation costs. The use of additional energy storage systems and a flexible energy management system will make it possible to further increase the proportion of own electricity consumption accounted for by photovoltaics – with a correspondingly positive impact on the electricity grid. For this purpose, the project partners are developing a cheaper battery storage system based on lithium-ion storage technology. Furthermore, they are developing an energy management system that integrates yield forecasts and also load profile analyses. The BMWi is funding this project as part of the funding announcement "R&D for Photovoltaics" with around 8 million euros.

SPECIAL TOPIC

Fine-tuning for high-performance cells

Dr. Glunz, you wish to further reduce the manufacturing costs for solar electricity and thus strengthen the competitiveness of the German photovoltaic industry. Which parameters need to be tweaked in your research to achieve this goal?

Glunz: The most important parameter is without doubt the level of efficiency. Many of the costs for the complete system are proportional to the surface area so that increasing efficiency will have a very positive effect. Simply reducing the material or manufacturing costs is not nearly as cost effective. This is why we are carrying out research, like many photovoltaic companies, into efficient high-performance solar cells.
Quickly transferring results from the experimental stage to industrial production is particularly important to us. That's why we have reproduced the entire value added chain at the Fraunhofer ISE: from crystallisation through to module technology. Efficiency levels of less than 20 percent are still common at the moment in production. We want to increase this figure with new solar cell concepts and innovative production processes.

What are the most promising approaches?

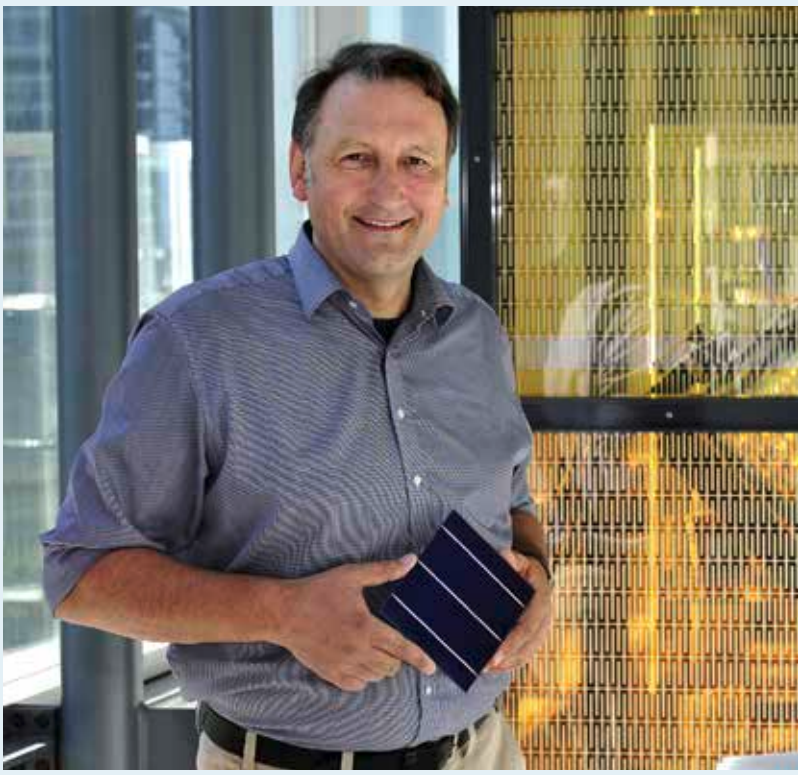
Glunz: One of the central themes of our research is to reduce the recombination of the light-induced charge carriers in the cell as much as possible. We want to prevent the positive and negative charge carriers neutralising each other because they are then no longer useful to the external electric circuit.
Therefore, we are actively engaged in the introduction of improved rear side passivation. In standard solar cells, the rear side is covered in metal and thus forms a huge defect area. We want to reduce these defects and have thus initially added a silicon dioxide or aluminium oxide layer to the rear side and only then fit the layer of metal underneath. The special challenge in this process is to make the layer permeable with openings because the positive charge carriers must be able to escape to the outside.

What solutions can you offer industry in this area?

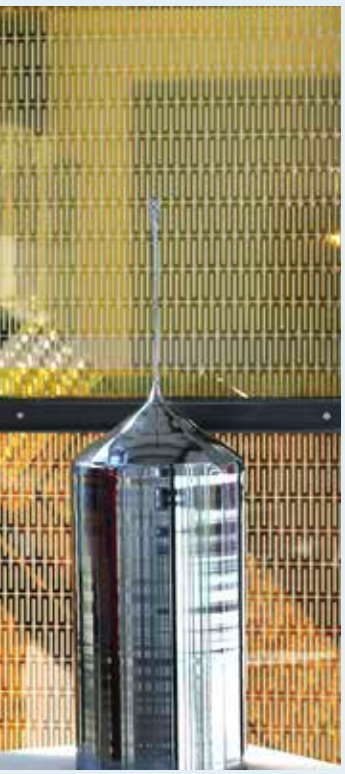
Glunz: We have developed an innovative manufacturing process for this kind of fine-tuning of the solar cells – for which we also have a patent. We firstly apply the passivation layer, then the metal and finally we use a laser to fire the metal through the insulating passivation layer to form optimal contacts. We have already been able to successfully transfer this LFC technology, which stands for Laser Fired Contact, to industrial processes.

What other successes have you been able to achieve in the past few years?

Glunz: Due to the improvements in the rear side of the cells, we were able to set a world record for multicrystalline solar cells in 2004 and have held it ever since. In order to achieve this world record of 20.4 percent efficiency for a solar cell produced in the laboratory, we also improved the structure of the front side of the cell. In multicrystalline silicon, it is difficult to perfectly capture the light due to the different orientations of the crystals. In addition, the number of electrically active defects is also relatively high. We have thus made the solar cells significantly thinner: from over 200 to 99 micrometres. The thinner the base material, the less significant the effect of the defects becomes.
The idea is one thing but its implementation requires a great deal of delicate handling. The decisive factor for us is that our research successes can also be used in a practical sense. Therefore, we work closely together with German solar cell manufacturers and mechanical engineers. This joint optimisation of the process steps leads to the continuous improvement of the cells. The world record set by our laboratory cell is sure to be beaten again soon.



What goals have you set for the coming years?
Glunz: In the short to medium term, we want to achieve a level of efficiency of 23 percent with inexpensive processes. We have lots of new technologies for achieving this in production – e.g. changing from p-doped to n-doped silicon. This reverses the entire structure of the cells and enables us to further reduce the effects of the defects.
Nevertheless, silicon solar cells only have a maximum efficiency level of 29.4 percent in the end. Therefore, we aim to develop a silicon-based tandem technology. We want to continue to use silicon cells but fit an additional solar cell with a larger bandwidth on top. This will enable us to better utilise the bandwidth of the light spectrum. There are several possibilities for this: On the one hand, a solar cell made of III-V semiconductors that we grow on the silicon solar cell or combine using wafer bonding. This involves compressing it at a high temperature so that we can achieve an efficiency level in the solar cell of over 30 percent. I am extremely confident that we can push the German photovoltaic industry forward along the entire value added chain with these innovative approaches. This is because we continue to be global leaders when it comes to innovation and quality.



Dr. Stefan Glunz is Division Director of "Solar Cells – Development and Characterization" at the Fraunhofer Institute for Solar Energy Systems ISE. He was awarded the Becquerel Prize by the European Commission in 2014 for his research in the area of high efficiency silicon solar cells

100 SolarWorld PV modules on the roof of the day-care centre Kalenborn in Rhineland-Palatinate save 9.7 tonnes of greenhouse gases per year and generate 17.6 megawatt hours of electricity.

PERC cells: the new solar cell generation

So-called AI-BSF technology (aluminium back surface field) has formed the basis for the industrial-scale production and further development of crystalline silicon wafer solar cells for more than a decade. The silicon wafer forms the core of the cell, with the side facing the sun holding the emitter, a passivation coating for the emitter and the electrical contacts. The rear of the cell has a full-surface layer of aluminium that creates the back surface field – an electrical field – and acts as an electrical contact for the rear of the cell. In the **HELENE** joint project under the coordination of SolarWorld Innovations GmbH, the aim is to now prepare PERC technology ("Passivated Emitter and Rear Cell") as the new generation of cells and a direct successor to AI-BSF technology for widespread launch onto the market. PERC technology is not completely new but is based on the already described AI-BSF technology. Instead of a full-surface aluminium layer, a dielectric layer, e.g. made out of aluminium oxide and silicon nitride (AlO_x/SiN_y), is added to the rear of the cell so that the aluminium only forms local contacts with the silicon wafer. The rear of the cell is still passivated here. Electrical and optical losses are reduced and the level of efficiency can be significantly increased.

HIGHLIGHT

Heterojunction cells from a new manufacturing concept

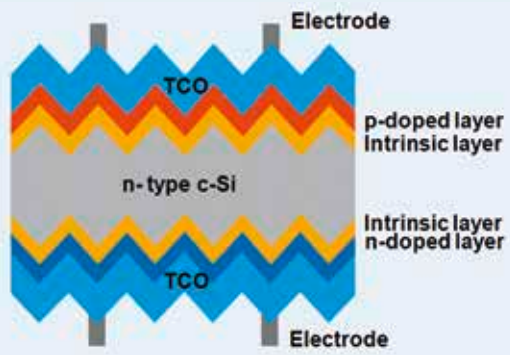
Heterojunction technology displays a great deal of potential for inexpensive high efficiency solar cells. It combines the advantages offered by two different types of silicon. The aim of the INNOHET project being conducted by SINGULUS TECHNOLOGIES AG, SINGULUS Stangl Solar GmbH and the Fraunhofer Institute for Solar Energy Systems ISE is to develop a new manufacturing process for heterojunction cells that will entail electricity generation costs of less than ten cents per kilowatt hour for installations in Central Europe. At the same time, the project partners are developing the corresponding plant technology.

The basis of the traditional heterojunction cell is the around 200 micrometre thick crystalline silicon wafer, where the element silicon takes on a regular lattice structure. Layers of amorphous silicon are applied to the front and rear of this wafer, which at around ten nanometres thick only account for around a ten thousandth of the overall thickness. Amorphous means they are unordered because the silicon atoms do not have any crystalline lattice structure.

One advantage of heterojunction cells is that they can be manufactured in relatively few steps. At the same time, they have a high level of efficiency – meaning that a higher proportion of sunlight is converted into electricity. The construction of individual layers that are fundamentally different from one another requires, however, an especially high quality surface both externally and at the boundaries between the layers. One approach being followed by the INNOHET project consists of further minimising the process chain, primarily the unnecessary and costly cleaning steps. They are developing an integrated plant concept for this purpose that is based on a continuous in-line process. It will contain, amongst other things, a plant with a new transport system in which the wafer is cleaned before the coating process. In this system, the wafers sit in transport pockets instead of on the usual transport rollers, which mean they can be guided free of contact through the cleaning bath.

Another approach is to develop alternative coatings. For example, the thickness of the hydrogen-rich amorphous silicon, which has up to now been applied directly onto the silicon wafer to passivate the wafer, can provide a compromise. In terms of its conductivity and absorption losses it should be thinner, yet in terms of the maximum mechanical tension it can withstand it needs to be a little thicker. Furthermore, the project partners are working on applying the finest possible contact structures to the cells, which is achieved using chemical vapour deposition. In turn, this requires the module technology to be adapted because the fine contacts can lead to increased serial resistance losses from the generated electricity. The BMWi is funding this project with around 3.3 million euros.

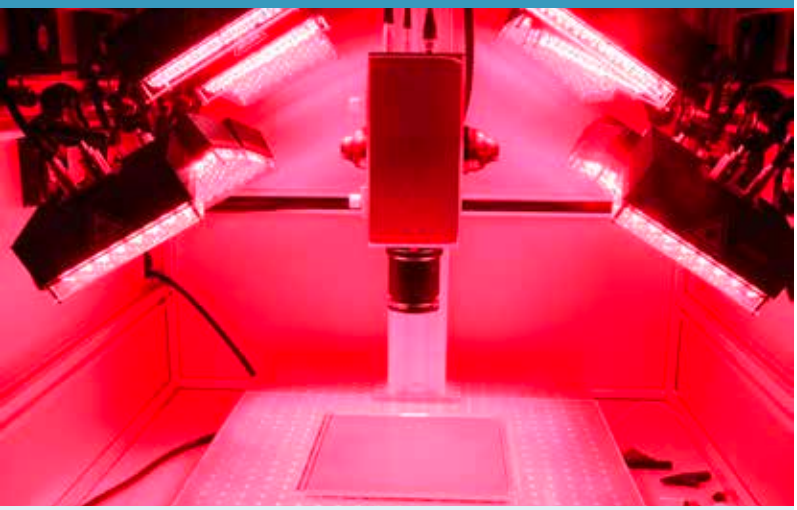
Structure of a heterojunction cell.



Higher quality through better quality control

Quality control in the production process results in high-quality products, with a lower number of rejects and thus lower costs – two important competitive advantages. In the optiCIGS project, two experienced companies in the field of CIGS thin-film photovoltaics – Manz CIGS Technology GmbH and Bosch Solar CISTech GmbH – are cooperating with leading research institutes to significantly improve the quality control process for this technology. Germany holds a technological advantage in this field that should be exploited further.

In CIGS thin-film photovoltaics, the chemical compound $Cu(In,Ga)(Se,S)_2$ is used as the semiconductor material that enables the sunlight to be converted into electrical energy. CIGS thus stands for the elements copper, indium, gallium and selenium. It is sometimes also supplemented by sulphur. In general, solar cells that are based on thin-film technologies are around one hundred times thinner than the silicon wafers that dominate the market – which saves material costs and energy costs. However, they are usually less efficient but this situation may change in the future. CIGS cells have a particularly high potential for efficiency that should be bet-

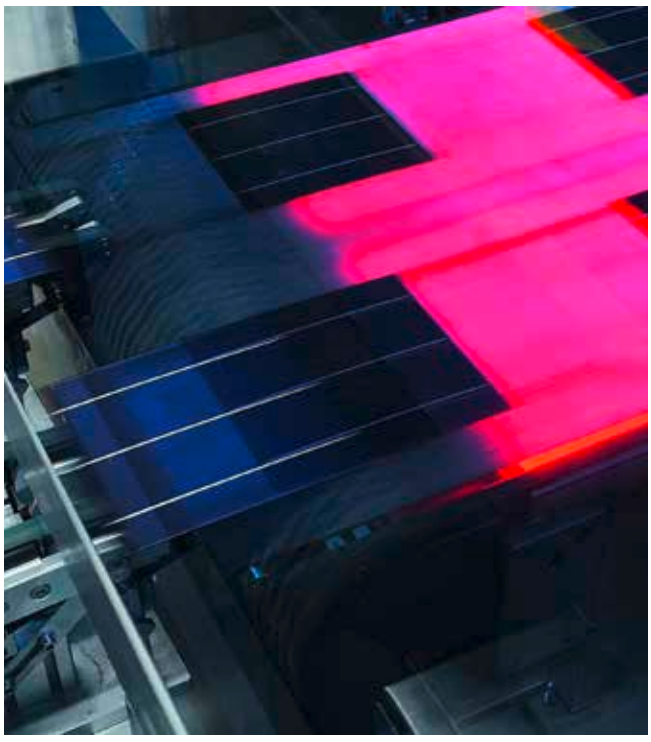


Measurement set-up for taking heat images of a small CIGS module with special LED lighting at the Ulm University of Applied Sciences

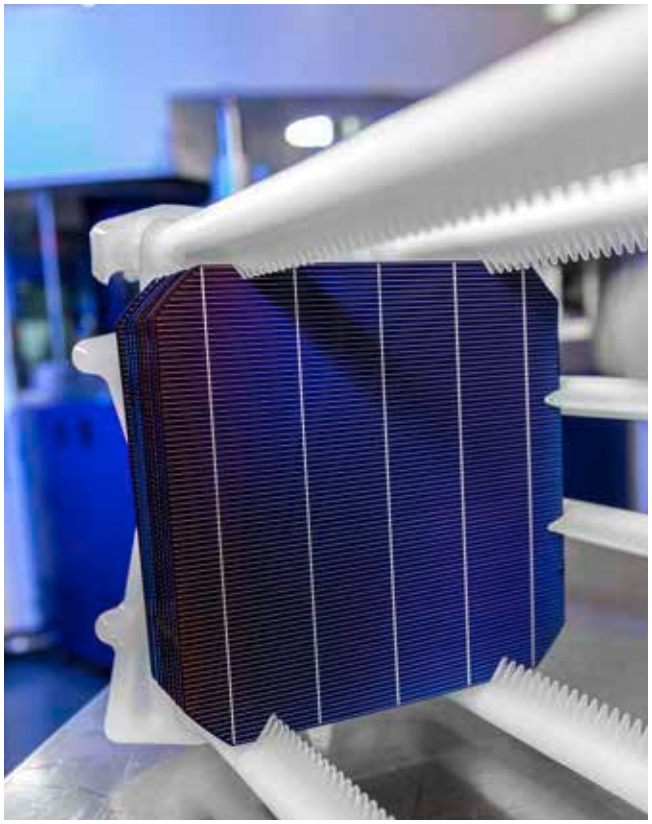
ter exploited. The highest efficiency levels for CIGS thin-film cells in research laboratories is currently 21.7 percent, achieved on a small surface at the ZSW Stuttgart, while in industrial production, module efficiency levels of 14 percent have been normal until now. Better production controls could also help to consciously reduce this gap.

The aim of the project is therefore to develop automated imaging processes that can be utilised in-line – during the production – and for different substeps of the production process in order to continuously check for and guarantee quality. The imaging processes collect physical parameters such as the heat of an object at a certain point and use this information to generate an image. One example is a thermal imaging camera. A defect – insofar as it will have an electrical impact and is therefore relevant – will generate measurable and hence visible heat. This enables the type, location and intensity of the defect to be identified. Another imaging process is based on electroluminescence: If voltage is applied to a solar cell, it will emit invisible infrared light (luminescence) that can be captured using appropriate cameras. If defects occur during production, they can be detected and localised using the heat or luminescence image created by the new imaging processes. This localisation of defects and their quantitative evaluation has not been possible up to now using standard processes. The following research institutes are cooperating in the project: ZAE Bayern (Bavarian Center for Applied Energy Research), Forschungszentrum Jülich GmbH, the Ulm University of Applied Sciences and the University of Oldenburg. The BMWi is funding this project with around 1.9 million euros.

In contrast to totally new cell concepts, industry can build on already existing processes for the production of the PERC cells, which would require lower investment costs in comparison. The HELENE project aims to systematically develop the required plants, materials and processes and gradually integrate them into the pilot line operated by the project coordinator. Furthermore, the project partners are developing extended simulation, characterisation and measurement methods that will describe, record and analyse the loss mechanisms of the cells, as well as cell-to-module electricity losses. In the process, the project aims to achieve efficiency levels of over 19 percent for multicrystalline silicon cells and over 22 percent for monocrystalline silicon cells. In combination with the work on module technology in the LAURA project (see above), the aim is thus to enable electricity generation costs of less than ten cents per kilowatt hour. Other project partners include the University of Konstanz, the Institut für Solarenergieforschung Hameln GmbH (ISFH), the Fraunhofer Institute for Solar Energy Systems ISE, the Fraunhofer Center for Silicon Photovoltaics CSP, Centrotherm Photovoltaics AG and Heraeus Precious Metals GmbH & Co. KG. The BMWi is funding this project as part of the funding announcement “R&D for Photovoltaics” with around 9.9 million euros.



Inspection of crystalline solar cells on an industrial production line



The record-holding PERC solar cell from ISFH with an efficiency level of 21.2 percent

PERC cells optimised for entry onto the market

The Institut für Solarenergieforschung Hameln GmbH (ISFH), now also a project partner in HELENE (see above), already optimised an industrial production process for PERC solar cells at the ISFH Technology Centre SolarTeC in its **HighScreen** project. As a result of continuous improvements to the processes for passivating the rear of the cells and the metal contacts, it was possible in combination with an innovative 5-busbar front design to achieve a record efficiency level of 21.2 percent, which is the highest efficiency level achieved worldwide for an industrially produced PERC solar cell. These cells used moncrystalline silicon. An improved silver paste developed by the project partner Heraeus Precious Metals GmbH also contributed to achieving this record. In cooperation with Singulus Technologies AG, ISFH has also developed a new ICP (Inductively Coupled Plasma) deposition method for AlO_x/SiN_y layers, which is now being deployed by Singulus in a production plant with very high deposition rates. In order to optimise the polishing of the rear of the PERC cells, ISFH has also further developed a wet chemical polishing process with Rena GmbH. The PERC solar cells are currently being tested by the project partner SolarWorld AG and other cell manufacturers around the world and are close to being launched extensively onto the market (see also HELENE project above). The BMWi funded this project with around 710,000 euros.

Reliably predicting the long-term stability of new products

Innovative photovoltaic modules with a high level of efficiency and low production costs are only beneficial if the lifespan of the product and thus the overall yield are also greater. In order to make judging these considerations easier for investors, the partners in the Fidelitas project under the coordination of the TÜV Rheinland Energie und Umwelt GmbH are developing methods which enable module degradation due to environmental influences to be quantitatively predicted, as well as to assess how successful respective countermeasures may be. Quick innovative tests will be designed that will already identify components or construction methods that may result in shortened lifespans for new products during their development. Partners in the Fidelitas project include, amongst others, the Fraunhofer Center for Silicon Photovoltaics CSP, the Institut für Solarenergieforschung Hameln GmbH (ISFH) and Vetro Solar GmbH.

There is currently a lack of reliable models and test methods for predicting the long-term stability of new products. The existing models are limited to sites in moderate climates. Furthermore, some fundamental degradation mechanisms have not been sufficiently examined and the real effects of ageing mechanisms are not known. The project partners are now working on expanding these models to resolve these deficits. The partners use reliable statistics about actual errors that occur in photovoltaic modules as a basis and are investigating the physical and chemical fundamentals behind the degradation mechanisms. They are investigating, amongst other things, corrosion of solar cells due to dampness and ageing of cells caused by UV light. Site-specific effects due to sand storms or hailstorms are also being carefully examined. Using numeric FEM simulations (finite element method), the ageing models are being transferred to photovoltaic modules based on real conditions in different climatic regions. In addition, the project partners aim to use the resulting findings to propose and conduct research into finding reliable and durable module concepts. The BMWi is funding this project with around 3 million euros.

Solar thermal power plants

Solar thermal power plants hold a position of great importance in sun-rich countries for transforming electricity generation into a renewable, climate-neutral system. The possibility of combining a solar thermal power plant unit with a fossil fuel-fired unit – constructing a so-called hybrid power plant – makes it possible to gradually introduce solar energy into the power supply system. The market potential is thus enormous.

Market developments in Germany and across the world

The global market for solar thermal power plants continues to be relatively restrained. In comparison to the previous year, growth in installed power plant capacities of 0.6 gigawatts was recorded. There is thus currently around 4 gigawatts of installed output globally. This low demand for solar thermal power plants also led to a significant reduction in production capacities in 2014. Nevertheless, German component manufacturers and suppliers hold a leading technological position.

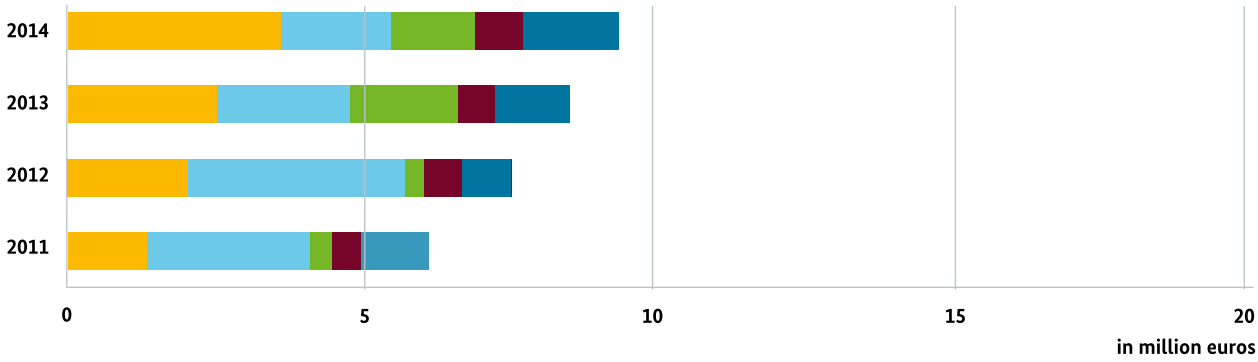
The low revenues generated by solar thermal power plants have resulted in the fact that cost reductions, which could have resulted through economies of scale with a larger number of products, could not be achieved. However, it was known at the end of 2014 that the latest generation of parabolic trough power plants that are currently being implemented in Morocco are set to achieve electricity generation costs of 12 cents per kilowatt hour – instead of the 17 cents achieved by older power plants.

Progress in research and development

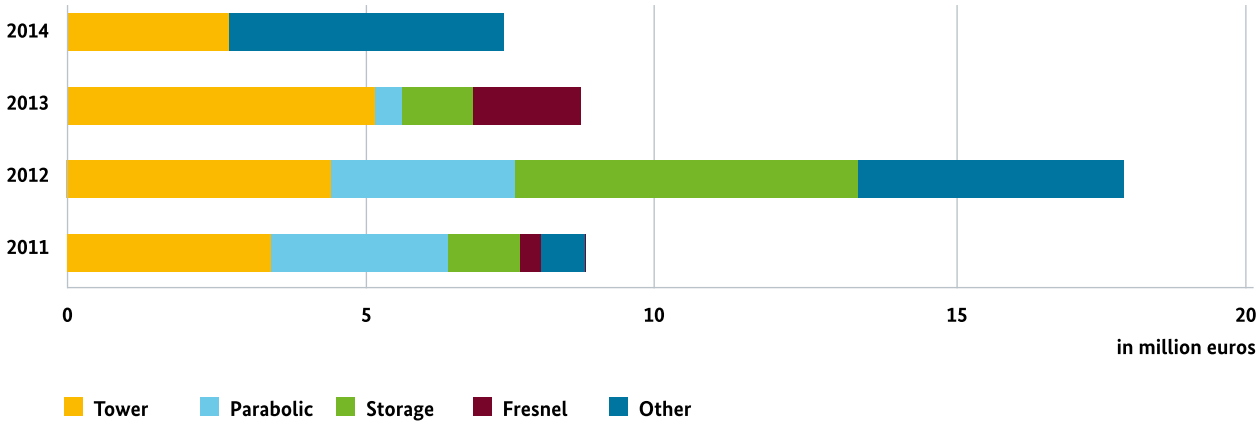
Parabolic trough technology with thermal oil as a heat transfer fluid can be considered the state-of-the-art technology for solar thermal power plants. A parabolic curved mirror concentrates the sun onto a tube – the so-called receiver – in which the thermal oil is circulating and thus heats it. A significant disadvantage of this technology is the relatively low operating temperature of 400 degrees Celsius, the resulting low power plant efficiency and the higher storage volumes required. The medium-term goal is thus to increase the operating temperature to over 500 degrees Celsius. Furthermore, the same considerations apply to Fresnel technology that utilises segmented rows of flat mirrors.

Significantly less experience has been gained in tower power plants than in parabolic trough technology. This technology utilises multiple, floor-mounted, large-surface mirrors to concentrate the sunlight onto a receiver in the upper section of a tower. There are currently a number of tower power plants with water vapour or salt as the heat transfer medium under construction or in operation. In parallel, German companies have developed a tower con-

Solar thermal power plants: Distribution of funding between 2011 and 2014



Solar thermal power plants: Trend in the volume of newly approved funding since 2011



cept that uses air as a heat transfer medium and is ideal for integration as a component in a gas and steam turbine power plant (COGAS). It is hoped that a demonstration project using this technology can soon be realised in the MENA region.

Strategy for research funding

The components of solar thermal power plants that are produced in Germany hold a prominent position when it comes to performance and quality. Therefore, research funding focuses on further increasing the competitiveness of German companies through the standardisation and qualification of all power plant components. In terms of the different forms of technology, the introduction of molten salt as a heat transfer medium forms the focus of the research funding. The aim is to push forward the development of new demonstration plants or test platforms for parabolic trough and Fresnel systems.

In the area of tower power plants, it is necessary to initially develop concepts for the use of molten salt due to the lack of experience in this area. Furthermore, technologies using air as a heat transfer medium – whose use also enables the achievement of temperatures significantly higher than 400 degrees Celsius – will be developed further.

The heat generated in solar thermal power plants can be held in thermal storage units for demand-oriented electricity production – an advantage offered by this technology. Therefore, the development of adapted storage technologies is also a focus of the research.

All of these issues can also be examined as part of the European SOLAR-ERA.NET (European Research Area).

In 2014, the BMWi approved new funding for 22 new projects with a total volume of 7.4 million euros (2013: around 8.7 million euros). At the same time, 9.3 million euros (2013: 8.4 million euros) was invested in ongoing projects, which represents a continuous increase in funding since 2010.

SPECIAL TOPIC

"CSP is unavoidable"

As a technology for generating solar electricity, photovoltaics (PV) has left solar thermal power plants (Concentrated Solar Power, CSP) far behind it both in terms of its costs and also its newly installed capacity. But what are the perspectives for CSP? Professor Dr. Olaf Goebel is Chair of "Renewable Energy Generation" at the Hamm-Lippstadt University of Applied Sciences. He previously held the position of Head of Engineering at Masdar Power and the world's largest solar thermal power plant at the time – "Shams 1" in Abu Dhabi – was developed under his leadership. He believes that CSP continues to be an important supplement to PV.

Professor Dr. Olaf Goebel, Chair of "Renewable Energy Generation" at the Hamm-Lippstadt University of Applied Sciences

How do you assess the current situation for CSP?
Goebel: The situation is relatively difficult in comparison to where we stood eight years ago. There was a major boom in Spain in 2007 due to their subsidy laws, which resulted in lots of power plants being built. However, not much has happened since. The technical development of PV has become more advanced and their economies of scale have improved – more are being produced per year, which has thus reduced the production costs. CSP has naturally been left behind as a result, with electricity generation costs being more expensive in comparison.

Where do you still nevertheless see an opportunity for this technology?
Goebel: The major advantage inherent in the CSP system is the integration of heat storage systems. A heat storage system is much cheaper than an electricity storage system. An important advantage is: The energy is stored before the final conversion stage. For example, if we have a CSP power plant with an output of 100 megawatts and equip it with a storage system so that it can run for twice as long then it can only deliver half of its output. The 100 megawatt power plant only has a power block of 50 megawatts with the same amount of energy and is thus much cheaper. The money saved can be used to pay for the storage system. In the case of PV and wind energy, there is no half-finished energy. If I thus want to install a storage system then I need to purchase batteries which represent an additional investment.

When will the advantage offered by storage come to fruition?
Goebel: As soon as there is a market that demands that the solar energy is available after the sun sets. CSP will then be cheaper. PV can only succeed in those markets where the electricity is welcome in order to save on coal and gas. But when a market requires solar energy as a dispatchable energy source then CSP is unavoidable. In contrast to PV, I will be able to eliminate an existing coal or gas power plant with CSP. I can also equip a CSP power plant with an additional burner so that it can run on natural gas on days without sun and on which the storage unit is not able to charge. This only makes the power plant around two percent more expensive.

When will this market exist?
Goebel: When the markets become oversaturated with solar electricity during the day. If Germany had the right climate (meaning sufficient direct solar radiation), we would already have reached this stage. However, those countries that do have the right climate are still far from reaching this point. The USA would need to continue expanding PV and wind energy at the same rate as previously for another ten years before they reach the same limits. The energy supply companies would only then say: We would now like to have CSP. Yet the question is: Will we still have a CSP industry by then?

To what extent can research and development help here?
Goebel: It can attempt to rescue the situation by using research to make the technology cheaper. An important topic is, for example, using molten salts as a heat transfer medium. Also, certain countries need to create a market for solar thermal power plant technology in the near future using suitable incentive structures. If the market were to once again pick up on this technology in approx. ten years, we don't want it to have to start from the position it is in today.

HIGHLIGHT

Economic efficiency for solar towers with salt as a heat transfer medium

The central theme of current research projects on solar thermal power plants is increasing their economic viability and thus increasing the number of new power plant projects (see also interview, p. 35). One focus of this research is the use of molten salts as a heat transfer medium. They can reach very high temperatures, which enables the particularly efficient operation of the conventional part of the power plant – steam generators and steam turbines with generators.

Therefore, salts have been increasingly used as a heat transfer medium for solar tower power plants in recent years. The first pilot plant Gemasolar with an output of around 20 megawatts was already connected to the grid in Spain in 2011, while the Crescent Dunes power plant with an output of 110 megawatts is currently being constructed in the USA.

In order to further increase the economic viability of solar tower power plants using molten salts as a heat transfer medium, the joint project **HPMS** coordinated by the Institute of Solar Research at the German Aerospace Center (DLR) is designed to explore all potential for reducing costs. The project partners believe there are potential savings to be made particularly in the receiver technology and also within the high-temperature solar circuit. The receiver is located in the upper section of the solar tower and absorbs the solar radiation concentrated onto it. The heat energy is transferred to the molten salt that flows through the receiver – which is subsequently fed through the high-temperature solar circuit to the conventional part of the power plant or a storage location. Only external receivers have been used up to now to capture the solar radiation, which are fitted around the tower. This enables the system of mirrors on the ground to be flexibly positioned – although the concept is sensitive to the wind and any salt that has cooled down can solidify in the pipes. The project partners believe that so-called "cavity receivers" can offer an alternative where the solar radiation hits the surface of the receiver material inside a cavity protected against the wind. For the receiver to work particularly efficiently at high temperatures, the solar radiation from the mirrors needs to be concentrated onto the receiver across a large difference in height – while at the same time minimising heat losses.

The joint project aims to achieve this with detailed design optimisations, the use of new coatings and the selection of a concept for suitable materials. The project partners will use a simulation of the most promising concept for a receiver that uses molten salts and plan to utilise this as the basis for the construction of a test receiver system for a subsequent phase of the project. Overall, the project aims to develop concepts for the receiver and also the high-temperature circuits that will optimise economic viability across the entire lifespan of the power plant.

Other project partners are Babcock Borsig Steinmüller GmbH, Bilfinger Piping Technologies GmbH, M+W Germany GmbH – Global Technology Services, STEAG Energy Services GmbH, Salzgitter Mannesmann Forschung GmbH and the FH Aachen University of Applied Sciences. The consortium is also being supported by associate partners BASF SE and VDM Metals GmBH. The BMWi is funding this project with around 1.4 million euros.

Receiver at the salt tower power plant "Crescent Dunes" in the USA

Heliostat from Solar Tower Technologies AG with fixed horizontal axis suspension

Selected funded projects

Overall concept for lower energy losses in tower power plants

The efficiency of a solar thermal tower power plant is determined by the largest possible proportion of solar radiation that it can convert into electricity. There are losses at every individual station, for example directly in the heliostat field, which means at the mirrors that reflect the sun's rays onto the receiver. The heliostats cast shadows over each other, blocking the rays from surrounding heliostats or deflecting them from the receiver. Losses also occur at the receiver itself due to the fact that only a proportion of the combined rays are absorbed or some of the absorbed thermal energy is lost. The Fraunhofer Institute for Solar Energy Systems ISE as the coordinator is working together with Solar Tower Technologies AG in the Heliopack project on reducing these losses through interrelated work packages on heliostats, their control systems, the design of heliostat fields and receiver technology.

In the "HelioAct" package, the project partners are developing new heliostats with higher optical precision. Another approach is to arrange fields of heliostats with fixed horizontal axes in a different way that is designed to produce a higher density of heliostats around the tower and a smaller focal spot on the receiver. At the same time, the partners are working on minimising the cost of the heliostats. In the second work package "HelioLoop", the focus is being placed on developing more precise control and targeting strategies for the heliostats. For example, camera-based methods are being examined for this purpose. The project partners are focussing in the third work package "HelioRec" on the development of a basic design for a molten salt receiver, as well as an absorption module for a volumetric gas receiver equipped with a fine ceramic tube system. The concepts aim to achieve operating temperatures of between 550 and 1,000 degrees Celsius. The BMWi is funding this project with around 2 million euros.

Standards enable cheaper financing

The electricity yield that can be expected from a planned solar thermal power plant plays a decisive role in the financing of the project. However, each company has used their own individual methods up to now to calculate the future electricity yield. Comparative calculations thus differ and unsettle investors, which is reflected in higher risk premiums. In the **CSP-Bankability** project, the Fraunhofer Institute for Solar Energy Systems ISE, Suntrace GmbH and Fichtner GmbH & Co. KG under the coordination of the Institute of Solar Research (SF) at the German Aerospace Center (DLR) are thus working on standardised methods to improve calculations for economic viability and thus establish cheaper financing conditions. The project partners are developing a handbook to standardise the methods for yield prognoses.

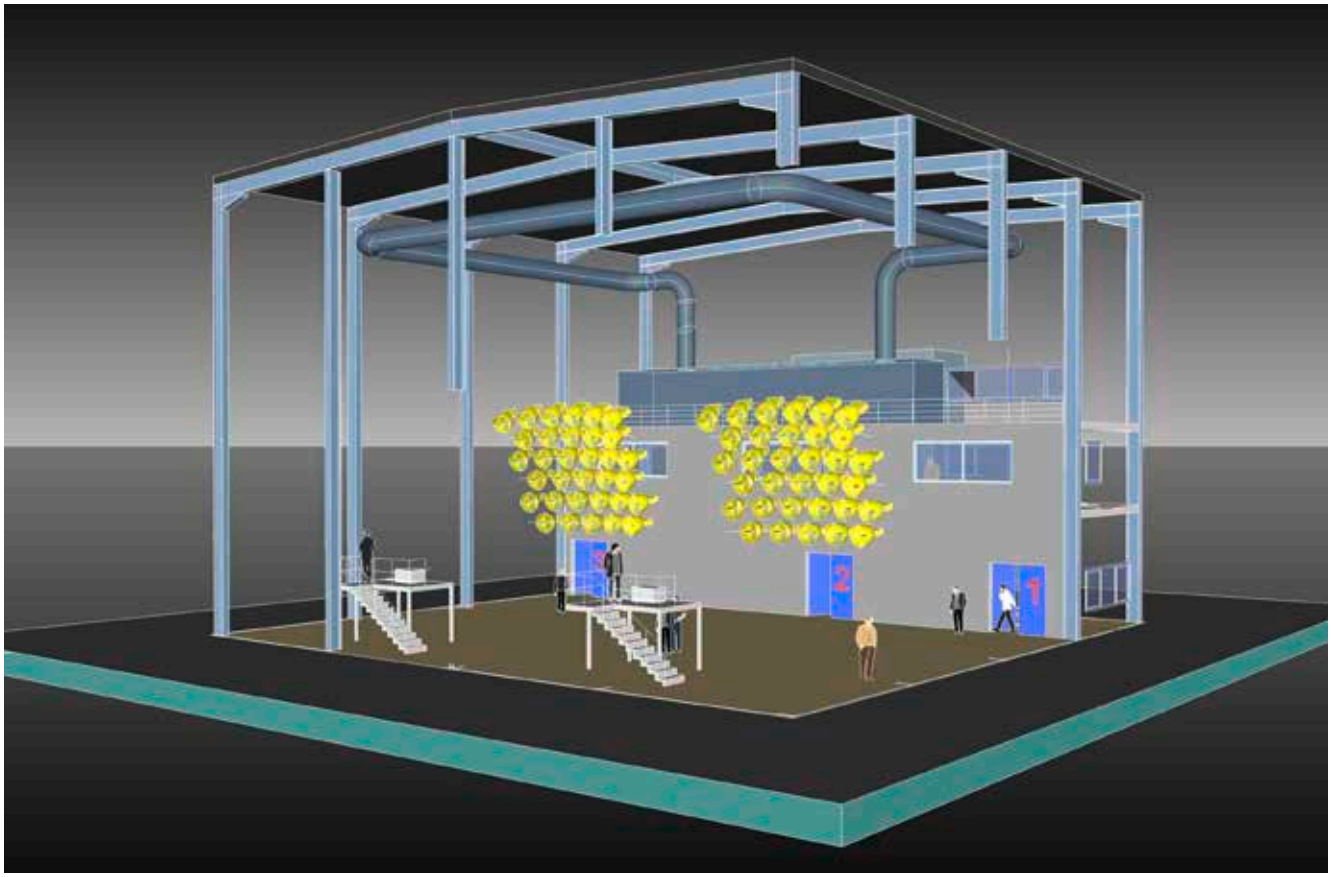
The handbook aims to describe all of the effects that must be taken into account for the yield prognosis. When the different calculation methods currently being used are compared, it becomes clear that, amongst other things, individ-

ual effects – such as the energy required for the starting up process – are taken into account in very different ways. Input and result variables have thus been defined differently up to now. Therefore, the available radiation might mean the actually measured direct radiation in one case, while in another case it describes a value already adjusted for the angle. The handbook aims to standardise all parameters, name the most reliable methods and specify various definitions. Where possible, uniform definitions and calculation methods will be developed for all CSP technologies such as parabolic trough power plants or solar thermal tower power plants. These can then be supplemented to fit specific technologies, or even for future technologies. In parallel, the project partners aim to push forward the quick implementation of the results as international standards through their participation in a scheme run by the International Energy Agency. The BMWi is funding this project with around 1.3 million euros.

Test stand: High-power artificial sunlight

In order to decide which materials and key components should be used in a solar thermal power plant, it must be proved in advance that they are reliable and durable. To enable tests to be carried out irrespective of the time of day or weather conditions, the German Aerospace Center (DLR) is developing the world's largest artificial sun. A modular high-power light system is being constructed at the Jülich Technology Centre in the MHLS project. Using around 80 electrically operated xenon short-arc lamps, whose light is very similar to natural sunlight, the aim is to achieve a radiation output of up to 200 kilowatts. The tests that will be able to be carried out as a result could accelerate the development of new solar technologies.

Design for the construction of a high-power lighting system: It works using electrically powered short-arc lamps, whose light is very similar to natural sunlight



In the performance range of between 100 and 200 kilowatts, the demand for systematic radiation experiments under precisely reproducible conditions has increased. Therefore, the testing facility will fill the gap between the high flow-density solar oven (up to 25 kilowatts) or the high-power light system (up to 20 kilowatts) at the DLR and the experimental solar tower power plants that have much greater performance levels than 200 kilowatts. The high-power lighting system will consist of multiple modules, which can be used individually or in groups. This will enable multiple small experiments to be run in parallel or for one experiment in the performance class up to 200 kilowatts.

The BMWi is funding this project with around 1.1 million euros. In addition, the DLR has received 2.4 million euros for the required investment from the Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia. ■

The image shows xenon short-arc lamps of the already existing and relatively smaller high-power lighting system in Cologne

Geothermal

Geothermal energy utilises the Earth's internal heat that is constantly present beneath the ground. In comparison to the fluctuating availability of wind and solar energy, it is continuously available and will thus make an important contribution to the energy mix of the future. Geothermal energy can be utilised for both generating electricity and directly for heating. The deep geothermal energy projects funded by the BMWi primarily focus on heat from geothermal reservoirs below 400 metres. However, significantly deeper boreholes of more than 1000 metres are common, which convey thermal water at temperatures of greater than 60 degrees Celsius to the Earth's surface. There are two principle types of geothermal energy: Hydrothermal geothermal energy predominantly utilises the hot water underground directly, while petrothermal geothermal energy utilises the heat stored in dry rocks.

Market developments in Germany and across the world

The most important regions for hydrothermal geothermal energy in Germany are the North German Basin, the Upper Rhine Graben in South West Germany and the Molasse Basin on the southern edge of Bavaria. In these regions, the natural increase in temperature with increasing depth is especially high; in some places it is up to 10 Kelvin per 100 metres so that even water temperatures of over 100 degrees Celsius can be found in the subsurface.

According to the German Geothermal Association (BVG), there were 26 geothermal heating plants or combined heating and power plants in operation in Germany in July 2014 with an installed capacity of 300.4 megawatts (thermal).

In addition to the four already operating sites in Insheim, Landau, Unterhaching and Bruchsal (picture above), further geothermal plants were completed at sites in Dürrnhaar, Kirchstockach and Sauerlach (all in Bavaria) in 2014. This means that there are now seven geothermal power stations in operation to produce electricity, which have an electrical installed capacity of 31.31 megawatts. Further power plants are currently under construction, for example, in Taufkirchen or Traunreut.

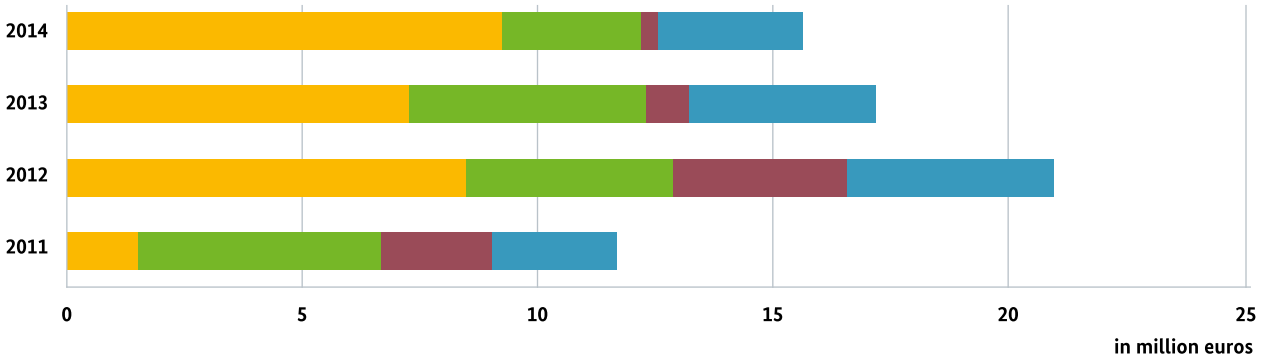
Furthermore, numerous scientific and technical projects were also successfully completed in 2014 – these have contributed to significant gains in knowledge. In order to economically utilise deep geothermal energy and correspondingly exploit the existing potential of the heat, further research is still nevertheless required.

Germany's installed thermal capacity of around 2,485 megawatts means it lies in fifth place worldwide for the utilisation of geothermal energy according to the BVG. First place is held by the USA (12,611 megawatts), followed by China (8,898 megawatts). These countries are followed by Sweden (4,460 megawatts) and Norway (3,300 megawatts). The statistics cover the installed deep and near-surface geothermal energy worldwide and are collected every five years. An update is expected at the forthcoming World Geothermal Congress 2015 in Melbourne (Australia).

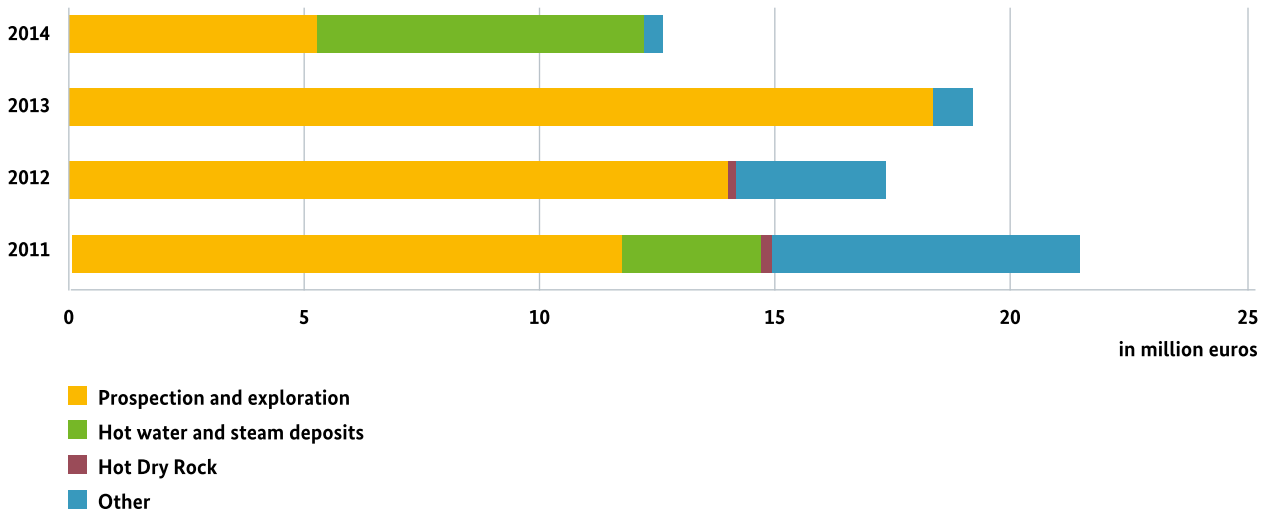
Progress in research and development

In order to tap the potential offered by geothermal energy as a continuously usable source of renewable energy, a great deal of research and development work has already been completed. Drilling technologies and the design of power plants, in which the heat extracted from the Earth is fed into district heating networks or converted into electricity, are being constantly improved. In addition, particularly suitable regions are being identified and opened up for development. Achievements can especially be seen in

Geothermal energy: Distribution of funding between 2011 and 2014



Geothermal energy: Trend in the volume of newly approved funding since 2011



SPECIAL TOPIC

Drilling with impulses

Whether a geothermal power plant can be operated economically is highly dependent on the cost of sinking the boreholes. Conventional drilling tools are slow and wear quickly, especially when drilling into hard rock. This increases the drilling costs and the economic risk. A promising alternative is offered by Electrical Impulse Technology (EIT). It makes use of the destructive effect of electrical discharges. In comparison to conventional drilling processes, it is hoped that this technology will save 30 percent of the drilling costs.

Professor Dr. Günter Kunze is Chair of Construction Machines and Conveying Technology at the TU Dresden

Why are you researching alternative drilling systems for geothermal energy?
Kunze: Almost all of the geothermically interesting regions in Germany are located in areas of crystalline hard rock. The tools used in the oil and gas industries are, however, only suitable to a limited extent for these types of rock. In rock such as granite or gneiss, currently it is only possible to utilise roller cone drill bits with special hard rock cutting teeth. They must be pressed down onto the bottom of the borehole with great force and rotated. This process causes a high level of mechanical wear on the drill bits. The metal quickly becomes blunt, which means that the roller cones need to be replaced often and new cones installed. This is a time-consuming and thus expensive process.

You are carrying out research into an EIT drilling system as an alternative. How does the drilling process with electrical impulse technology work?
Kunze: The electrical impulses are created directly in the borehole. A discharge through the rock is created by two electrodes with different electrical potential – similar to a bolt of lightning. The voltage level is between 300,000 and 400,000 volts. We force this lightning bolt through the rock, it discharges and tears apart the rock which can then be removed. In the same way as when using conventional drilling technology, the rock is then removed and the drill can sink a little deeper. In this process, the electrodes simply lie loosely on the bottom of the borehole and do not need to rotate. The phenomenal thing about EIT is that there is no wear whatsoever. This means that even the non-productive time spent replacing tools in conventional drilling processes is drastically reduced.

What other advantages are offered by EIT?
Kunze: We predict drilling speeds of at least two metres per hour for the new system. This means, for example, an EIT drill can operate twice as fast in granite and up to ten times longer than conventional drill bits. Consequently, the overall drilling time can be drastically reduced. This means that the use of EIT can save up to 30 percent of the drilling costs in comparison to conventional drilling processes.

What challenges need to be faced and what are the next steps?

Kunze: The greatest challenge is to accommodate the different electrical components in the small installation space and to do so in such a way that they can withstand the tough conditions in a bore hole. The housing and the electrodes must be able to cope with temperatures of up to 200 degrees Celsius.
Furthermore, there is of course no mains socket in the borehole. This means that the energy needs to be generated in the drill string itself. This is the next step: So far, we have fed the energy down into the borehole via a cable, but now we aim to develop a complete system that generates the energy directly within the system itself.

A piece of rock drilled with electrical impulse technology

the Molasse Basin in Bavaria, where the supply of heat from deep geothermal energy can meanwhile be reliably utilised. The aim in this region is now to further increase the average output per power plant.

The range of funded projects in 2014 is very large: Alongside projects designed to reduce the exploration risk in the search for new geothermal reservoirs, there are also a number of funded projects focusing on the development of alternative drilling processes or improving the pumps used for geothermal energy. Other projects conduct research into the behaviour of geothermal reservoirs or monitor existing geothermal power plants. The portfolio is rounded off by projects dealing with the issue of material corrosion or the performance of special components as part of a geothermal power plant. The aim of the research work is to collect operational experience and thus optimise the operation of future plants, as well as to further reduce the investment risk and the costs of extracting geothermal energy overall.

In view of the significant potential and expected contribution of geothermal energy to a future energy system based on renewable energy, the BMWi is continuing to support relevant research projects.

Strategy for research funding

The research projects currently being funded encompass all stages of the value chain for geothermal energy. The primary goal is to further reduce the cost of projects in order to make geothermal energy economically viable nationwide. Contributions towards the achievement of this goal are made by technological developments in all project phases: in the planning of the project, the exploration of the target region, the drilling/erection/construction work and the testing and operation of the completed power plant. In particular, the deep boreholes must be completed more quickly and less expensively as they currently account for the main part of the investment costs. The operation of finished power plants must be more efficient, low maintenance and reliable. Alongside further technical developments in geothermal energy, concepts for improved public relations work are now a fundamental component of successful research projects. And last but not least, the conditions must be created for enabling geothermal energy to be utilised in those areas that have not yet been exploited or which prove less suitable.

In the area of geothermal research, the BMWi approved new funding for a total of 15 projects with a funding volume of around 12.7 million euros in 2014 (2013: 19.2 million euros). At the same time, around 15.6 million euros was invested in already ongoing research projects (2013: 17.1 million euros).

Selected funded projects

Innovative piping system for boreholes

Drilling a borehole many kilometres into the ground is very expensive. Innovative drilling methods seek to reduce the associated costs because it is these costs that significantly hinder the further expansion of deep geothermal energy as a technology for generating electricity in Germany (see also the box on this theme, page 42, 43). Baker Hughes INTEQ GmbH were able to demonstrate in their **Geothermal Piping System** project how drilling costs could be theoretically reduced by up to 30 percent. The researchers followed a holistic approach, investigating the three subject fields of monobore construction, automation of the drilling process and borehole safety and integrity.

A borehole drilled using conventional technology starts with a large diameter and tapers as the depth increases – similar to a telescope. In contrast, monobore borehole construction produces a cased borehole with a uniform diameter from the top to the bottom by installing continuous piping in segments directly during the drilling of the borehole. This makes it possible to avoid using the casings previously necessary, as well as the round trips for their installation, resulting in faster drilling times, lower material usage and thus savings of up to 15 percent. The challenge faced in monobore construction is primarily the underground expansion of the installed casing pipe during the drilling to stabilise the borehole, as well as the underground connection of the pipes with a welding process instead of the usual threaded connectors.

The scientists were able to make considerable progress in these areas. The precise alignment of the individual components before the welding process and the achievement of a high-quality connection presented themselves as particular challenges in this process. In the project, a prototype for a welding robot was developed in cooperation with the Leibniz Universität Hannover, which is based on MIAB (Magnetic Impelled Arc Butt) welding technology and

Welding robots for casing pipes

fulfils the requirements described above. The project partners were able to successfully complete the first tests of the welding equipment on original scale industrial applications.

In addition, the researchers developed a detailed concept for the automation of the drilling and piping process. With the aid of a specially developed algorithm, it was possible to find the optimal settings for the drilling system, such as drill bit load, speed and flushing rate, based on data measured underground. Applying this method can increase the drilling progress by 50 to 100 percent. In concrete terms, this resulted in cost reductions of up to 10 percent for one of the geothermal energy boreholes in the Molasse Basin in Southern Germany that had a typical end depth of around 4,500 metres.

HIGHLIGHT

Measuring, understanding and reducing earth tremors caused by deep geothermal energy processes

In order to utilise geothermal energy for generating electricity, hot water is pumped to the surface from many kilometres below the surface and then fed back after it has been used. The balance of forces underground can be disturbed by this intervention, which can result in "induced" – i.e. caused by human activity – seismically verifiable movements in the earth.

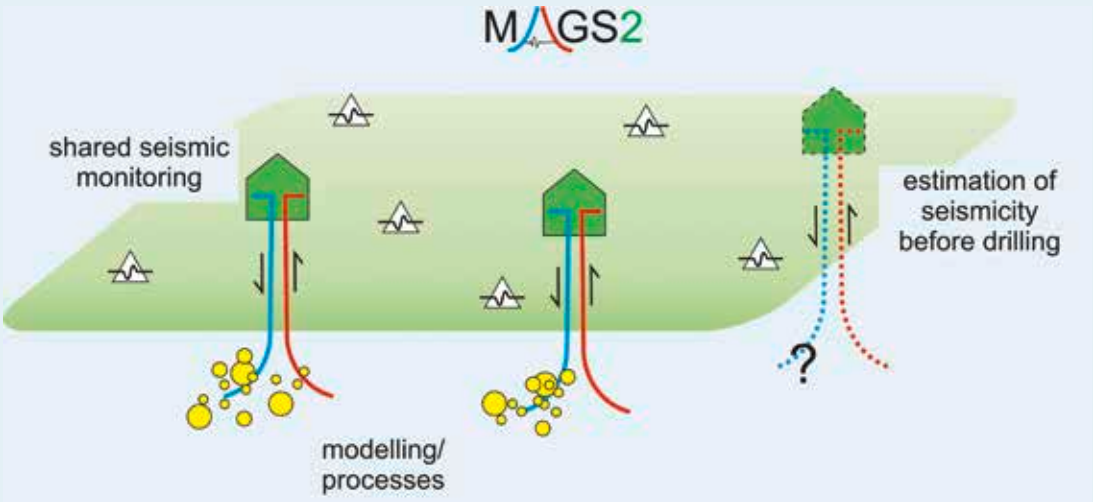
This so-called induced seismicity is generally so limited that it can only be measured using highly sensitive sensors (seismic monitors). Nevertheless, there have already been cases near to geothermal power plants, such as in Landau, Insheim or Unterhaching where small earthquakes could be felt at the Earth's surface. In order to avoid this occurring, it is necessary to fundamentally investigate and understand the causes, which can originate in both the subsurface itself or due to the operating procedures in the power plant. Research is being carried out in this area by a group under the coordination of the Federal Institute for Geosciences and Natural Resources (BGR) with the project name MAGS2.

The preceding project MAGS focussed on the concept of controlled water circulation: Precise observations of the seismic activity using sensitive sensors make it possible to adjust the operation of the power plant as soon as certain maximum values have been reached. For example, the pumps can be slowed down. In MAGS2, the project partners are developing the concept further – not only monitoring individual power plants but rather a combination of a number of nearby power plants, so-called complex geothermal fields. The scientists are researching the extent to which the power plants can mutually influence each other and whether it is necessary to maintain a minimum distance between them. By creating interfaces between different seismometers from various operators, the aim is to develop a complex network in which all available data and evaluations can be exchanged in real time as far as possible. In order to better understand and thus reduce the seismic risks, the aim is also to significantly improve previous models used to describe how vibrations in the earth reduce as the distance to the source of the seismic wave increases. Amongst other things, the project partners are also including the local properties of the subsurface in the calculations. Furthermore, the project aims to make it possible to estimate how susceptible an area is to the occurrence of earthquakes even before drilling takes place.

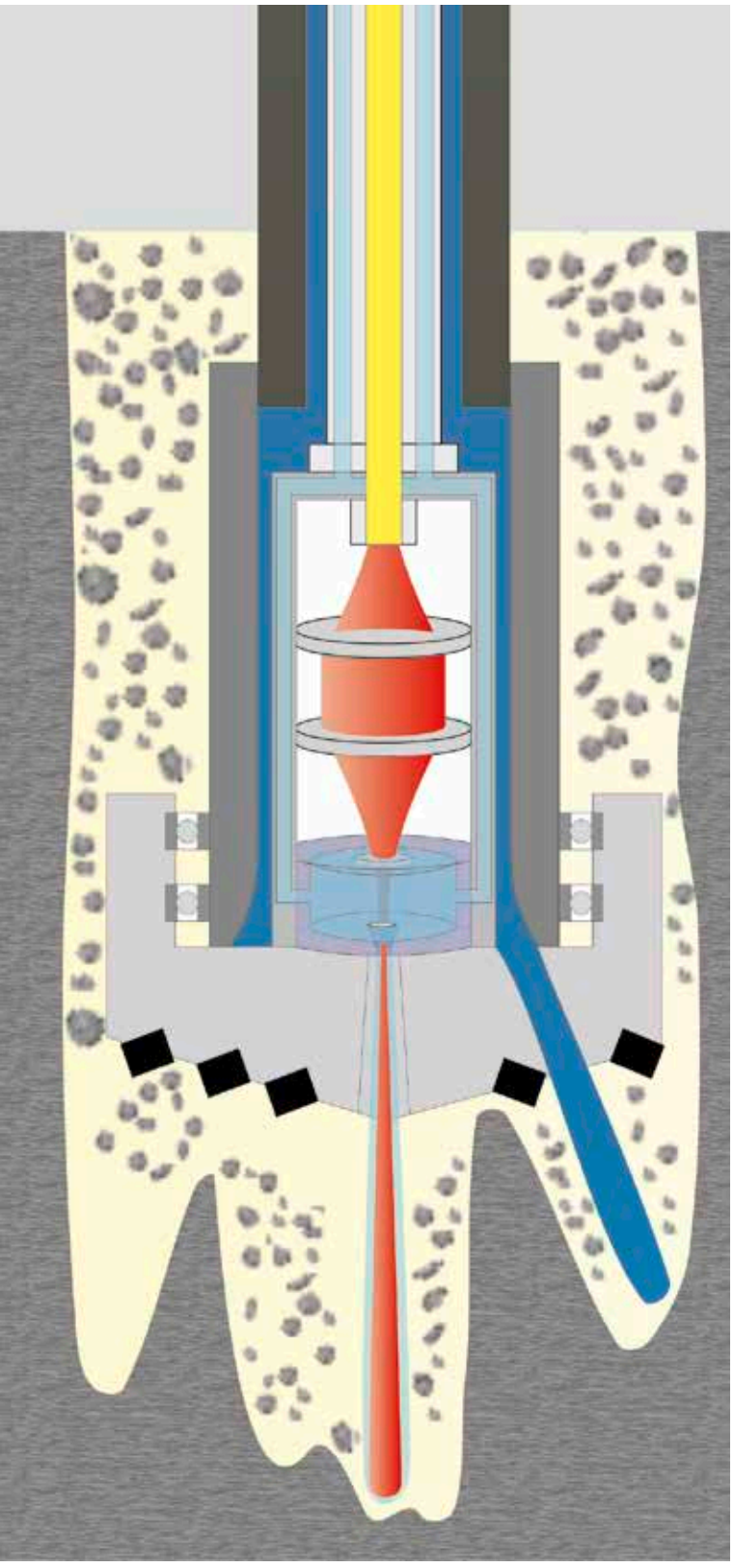
Other project partners in MAGS2 are the LMU Munich, the Ruhr University Bochum (RUB), Kiel University (CAU), the Freie Universität Berlin and the Energy Research Center of the Clausthal University of Technology and the TU Bergakademie Freiberg. In addition, numerous plant operators and regional geological agencies are contributing to the work.

The BMWi is funding this project with around 3 million euros.

Schematic diagram of the different fields of work within the MAGS2 project



Sketch showing the principles of a new drilling method in which water and laser jet drilling processes are combined



The components for monitoring and controlling the integrity of the borehole are closely connected with this automation concept. Baker developed algorithms and programmes for improved modelling and prediction of the underground pressure conditions in both the rock and also the drilling fluid. The danger of borehole breakouts can be significantly reduced in this way.

The BMWi has funded this project with around 4 million euros.

A laser with a water jet for faster drilling

Another innovative approach for reducing drilling costs was followed by the LaserJetDrilling joint project under the coordination of the Fraunhofer Institute for Production Technology IPT. The project partners aim to develop an alternative to the rotary method that has been predominantly used up to now by using a combination of water and laser jet drilling. In the case of the rotary method, a roller cone rotates on the end of a long drill string constructed out of individual pipes, whereby the rock is broken up mechanically. The process itself is extremely slow and causes a high level of wear to the drilling tools – with the entire drilling string needing to be completely dismantled a number of times for the replacement of components.

Drilling using a combination of water and laser jets is designed to enable deeper boreholes to be completed quickly and without any wear. Both processes complement each other: The laser beam makes it possible to quickly and efficiently remove solid rock, while water jet drilling enables fast tunnelling, particularly through loose rocks. In order to protect the laser optics against contamination, the laser beam is directed through the water jet. The principle of water jet guided lasers has already been used for micro applications such as cutting silicon wafers and the technology is available from the company Synova S.A., one of the partners in the LaserJetDrilling project. Other project partners include Herrenknecht Vertical GmbH, IPG Laser GmbH, KAMAT Pumpen GmbH & Co. KG and the International Geothermal Center (IGC) at the Bochum University of Applied Sciences.

The BMWi is funding this project with around 3 million euros.

Typical limescale deposits at the pump inlet

Pump sensors monitor operating conditions

Pumps are a critical element in the operation of a geothermal power plant. In comparison to their application in oil extraction, these pumps require significantly higher volumetric flows and performance, while crystalline precipitations such as calcite in the thermal water make their use more difficult. In their **Centrifugal Pump** project, Baker Hughes INTEQ GmbH is thus working on improving the reliability of electrical submersible centrifugal pumps for use in both the Molasse Basin in Southern Germany and the North German Basin. The project aims to redevelop critical components of the pumps and prove their effectiveness in long-term laboratory tests. The company is also utilising its high-temperature test rig for this work, which was developed during its earlier "Optimised Geothermal Pumps" project. This means that, for the first time, the long-term operation of up to 40 metre long high volume pumps with 2.5 megawatts of electrical output at water temperatures of a maximum of 190 degrees Celsius is now possible.

One focus of the new project is the development of a high-temperature pump sensor specially developed for geothermal energy. This sensor is installed underneath the electric motor and is notable for its high dielectric strength and temperature stability. In addition, the sensor is combined with a system comprising multiple measurement points for measuring vibrations in the pump string, which can occur, for example, due to imbalances or play in the radial bearings. These measurements have only been taken up to now at the lower end of the pump string. Furthermore, additional measurement methods will be investigated and evaluated for analysing the motor oil during the operation of the pump. This improved underground sensor system should make it possible to monitor critical operating parameters and thus avoid any operating state that may cause damage.

The BMWi is funding this project with around 4.1 million euros. ■

Hydropower and marine energy

Hydropower uses the flow of water – primarily in rivers or from reservoirs – to generate electricity. The kinetic energy in the moving water is converted into mechanical energy via turbines or water wheels, from which electricity is produced by generators. In the ocean, there are in principle three different energy sources that can be utilised: Ocean currents, caused by varying solar radiation in different regions, tidal energy, produced by the gravitational attraction between the moon or sun and the ocean, and wave energy, which is primarily caused by the effect of the wind on the surface of the water.

Market developments in Germany and across the world

A number of different systems have been developed to utilise wave energy. Wave power plants based on the principle of an oscillating water column (OWC) are well proven. The rising and falling column of water in this system compresses and decompresses air in a chamber. The resulting air flow then drives a Wells turbine. Other types of wave power plants capture the wave energy via a floating body that moves with the waves and drives a generator via joints, cables or hydraulic intermediate systems.

Energy from ocean waves can be harnessed at many sites using comparatively small power plants. In addition, wave power plants could be combined at a later stage with the operation of wind parks. The combination of these two technologies could provide a more even supply to the connected power grid because the yields provided by wind and wave energy are both temporally and spatially decoupled. However, the level of efficiency achieved by systems for converting wave energy into electrical energy has so far only reached around 35 percent. In order to try to significantly increase the level of efficiency, this topic became the focus of research funding from the BMWi in 2014 and a joint project for the further development of wave power plants has been approved.

Alongside its future use in the German Bight, this technology is also expected to provide export opportunities for German companies.

Progress in research and development

The advantage that hydropower and marine energy has over wind energy and photovoltaics is that energy can be supplied more or less constantly over time, or at least the supply can be predicted more reliably. Hydropower is considered a tried-and-tested source of energy. It was possible to further improve the ecological compatibility in this field in 2014 through targeted research projects that were funded by the BMWi. Marine energy offers great potential but is still at the demonstration stage worldwide.

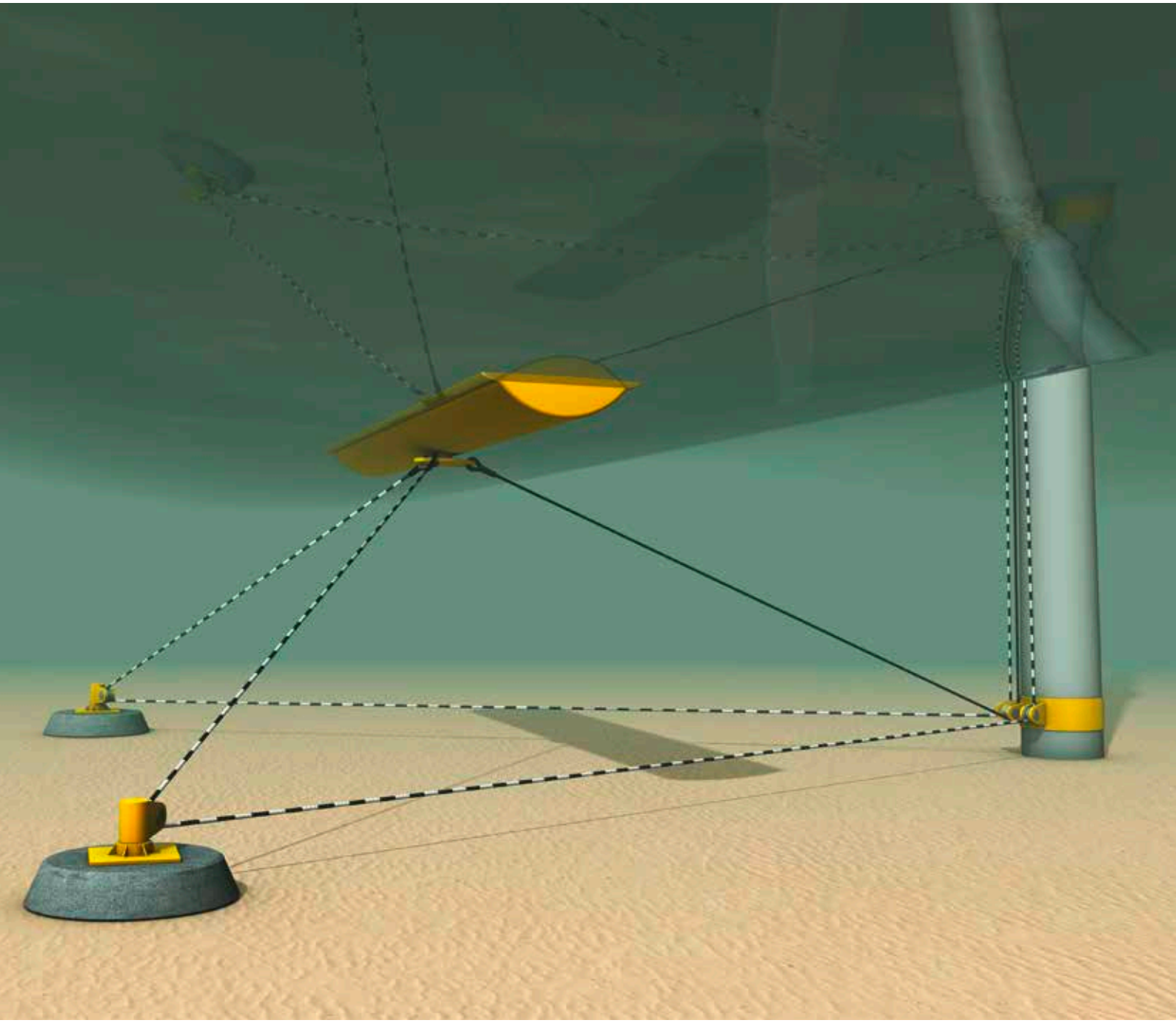
Strategy for research funding

Technology in the area of hydropower is largely mature. Nevertheless, a focus of the research funded by the BMWi remains the improvement of the ecological compatibility of the power plants.

In order to make greater use of the potential offered by marine energy for energy generation in the future, the BMWi will continue to remain active in this area and contribute to the realisation of relevant projects of a demonstrative nature.

In the area of hydropower and marine energy, the BMWi approved new funding for a total of 6 projects with a funding volume of around 2 million euros in 2014. At the same time, around 1.2 million euros were invested in already ongoing research projects.

Large water dam in Rappbode



Rope kinematics used in the NEMOS-system.

Selected funded project

Higher levels of efficiency through hydromechanical adaptation

If the relatively small wave power plants were to be installed in the exclusive economic zone of the German Bight, for example, an output of up to 25 kilowatts per metre of wave crest could be achieved. In order to increase the insufficient levels of efficiency offered by this technology up to now, a NEMOS power plant concept has been developed as a complete system that can increase efficiency levels to over 65 percent. The partners in the **NEMOS** project include NEMOS GmbH (as the coordinator), Schaeffler Technologies AG & Co. KG, LIROS GmbH, the Development Centre for Ship Technology and Transport Systems (DST) and the University of Duisburg-Essen. The concept is based on specialist hydromechanical knowledge and is implemented in an inexpensive way – the system is correspondingly aligned to the direction of the waves using ropes made out of highly resistant plastic. The movement characteristics are adapted to the current height and length of the waves in order to optimise the yield. In addition, NEMOS can be submerged if required to enable the quick regulation of electricity production and also to avoid any damage that could be caused by extreme swells. For the purposes of increasing the lifespan of the system and ensuring low levels of maintenance, all of the sensitive components such as the control system and generators are housed outside of the moving system and protected against sea water.

The concept has already been tested at a scale of 1:5 in natural swell. The project will continue to further develop all of the components to deliver reliable long-term operation in the full-scale version. The NEMOS–system will ultimately be installed as a test facility at a scale of 1:1 in the North Sea.

The BMWi is funding this project with around 1.7 million euros.

The NEMOS-system being tested at a scale of 1:5 in natural swell in Limfjord in Denmark

Power plant technology and CCS

In accordance with energy policy targets, the use of renewable energies in Germany should cover 80 percent of gross electricity consumption by 2050. A significant proportion of German electricity consumption will, however, be generated by fossil-fired power plants for the foreseeable future to cover the 20 percent of the residual load required. Therefore, there is continuous research in Germany into more efficient power plants, their flexibility in operation and fuel, the associated materials and components, as well as into CO_2 separation processes, CO_2 transport options and CO_2 systems.

Market developments in Germany and across the world

The use of renewable energies in Germany should cover 80 percent of gross electricity consumption by 2050. However, the proportion of gross electricity generation accounted for between 2005 and 2013 by brown and hard coal was still between 41.5 to 46.4 percent and by natural gas between 10.5 and 14.1 percent. As a result, fossil fuels still make a significant contribution to electricity generation in Germany.

Nevertheless, the amount of brown coal used is falling continuously. The reason for this is the improved utilisation of the fuel – which is a direct result of the replacement of old power plants with new, modern and more economical power plants that are more efficient.

In the area of power plant technology, German operators, manufacturer and research institutions are still among world leaders. Although there are currently hardly any foreseeable new construction projects in the area of thermal power plant technology in Germany, this field is heavily oriented towards export and is involved in numerous new projects, primarily in the Asian market.

In Germany, fossil-fired power plants are mainly covering the residual load required for the security of supply for domestic industrial sites during the expansion of renewable electricity generation and cushioning the increase in electricity generation costs. The residual load is the level of supplied electrical output not counting volatile energy sources such as wind power.

As renewable energy sources comprise fluctuating generating technologies and there are only limited storage capacities, sufficient thermal power plant capacities are required to provide a secure energy supply. These power plants will deliver a sufficient supply of electricity to stabilise the system when the proportion provided by renewable energies falls.

Progress in research and development

In order to preserve fossil resources and minimise CO_2 emissions power plants are being continuously optimised. Modern brown coal power plants can thus now achieve efficiency levels of over 43 percent and modern hard coal power plants can reach 46 percent. Combined cycle gas and steam turbine power plants (CC) reach overall efficiencies of more than 60%. The most effective and modern CC power plant in the world is located in Irsching.

These successes were made possible by the research and development measures at non-university research institutions, universities and industry in Germany . This strategy began 25 years ago with the foundation of AG Turbo (see the box on the theme of COORETEC), which aligned and coordinated pre-competitive, application-oriented research into turbo machineries in Germany. The global market share held by turbo machine manufacturers in Germany rose with the help of this initiative to the current level of over 30 percent within 25 years. This is not least due to the increases in efficiency that have helped to successfully minimise CO_2 emissions: in stationary gas turbines to almost 40 percent and in combined processes in a gas and steam power plant with waste heat recovery to above 60 percent.

It is now ten years since the Federal Ministry for Economic Affairs and Energy also founded the COORETEC initiative (see box on this theme) in order to identify development requirements and to discuss and initiate ideas for new research and development projects by calling on recognised specialist expertise.

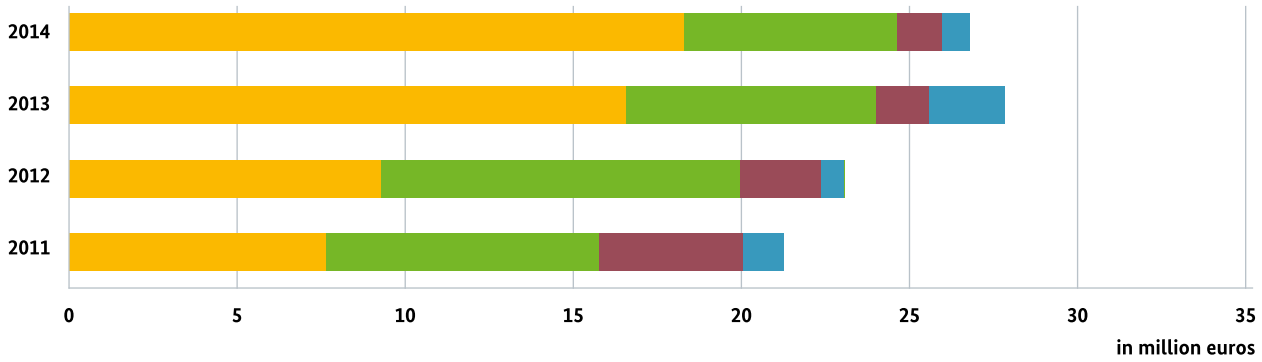
In the area of CCS (Carbon Capture and Storage), research and development projects are investigating, for example, energy efficient advanced CO_2 capture technologies, CO_2 storage concepts, risk analyses, monitoring and different transport options and transport components.

Strategy for research funding

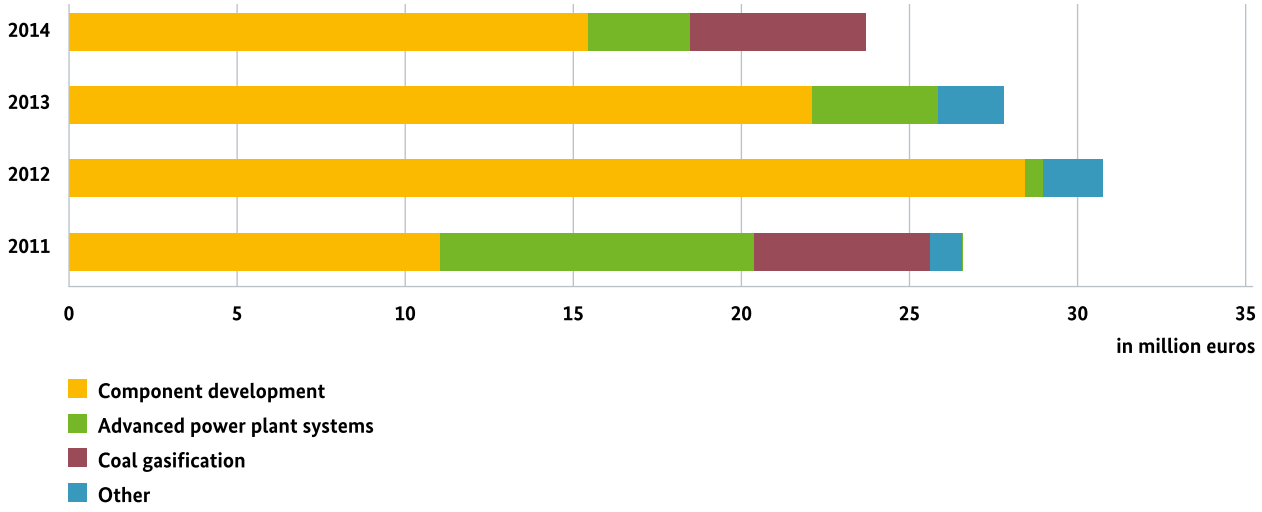
The expansion of renewable energies has also increased the demands placed on the operation of power plants because efficiency levels need to be optimised for partial and minimum load operation and the lifetime of the power

PCC pilot plant for CO_2 scrubbing in Niederaußem (also see page 57)

Power plant technology and CCS: Distribution of funding between 2011 and 2014



Power plant technology and CCS: Trend in the volume of newly approved funding since 2011



plants and their components optimised for rapid load changes. On the one hand, this means securely covering energy demand in the event of a lack of wind, cloud cover or at night, while on the other hand, it requires retrofitting measures or new power plant constructions for adapting to the changed framework conditions. This makes additional research and development necessary to ensure that power plants can operate in these highly changeable operating modes. Corresponding research programmes have been initiated for this purpose. In addition, newly gained knowledge and findings – also from ongoing operation – have helped to identify other required steps. This covers a whole range of topics from material testing and development, strengthening and developing components, long-term stability measures, lifetime and maintenance strategies. In order to enable completely flexible modes of operation, the ability to use different fuels and thus fuel-flexible combustion systems also play an important role. Other key research areas include the economic operation of fossil fuel power plants at run times of only a few thousand hours of full load and partial load operation per year, as well as the recycling of fossil raw materials in the event of reduced electricity generation.

Furthermore, research into storage options in the area of thermal power plants plays a significant role. This is because the supply of electricity is higher than demand in time of strong winds or high levels of solar radiation. This leads to surplus electricity that currently has to be supplied at negative prices.

In the area of power plant technology and CCS, a total of 26.7 million euros of research funding was provided by the BMWi to 233 ongoing projects in 2014 (2013: 27.8 million euros). A total of 23.8 million euros (2013: 27.8 million euros) of funding was provided to 55 newly approved projects.

SPECIAL TOPIC

10 years of COORETEC: intelligent power plant technology

The reduction of CO_2 emissions is one of the greatest challenges in the context of climate change. Generating electricity from fossil fuels more efficiently and with lower emissions is thus an important task. Despite the increasing share of electricity generation accounted for by renewable energies, the demand from the economy and society for a reliable and affordable energy supply means that it is not possible to dispense with conventional energy sources. This is even more important due to the fact that the increased feed-in of renewable energies causes fluctuations in the grid and conventional power plants have to cover the residual load or compensate for a temporary lack of electricity from renewable energies.

Therefore, the Federal Ministry for Economic Affairs and Energy laid the foundations for research and development into more efficient and low emission fossil fuel-based electricity generation with the COORETEC initiative in 2002. COORETEC stands for CO_2 REduction TEChnologies and is part of the German federal government's **6th Energy Research Programme**. The BMWi has provided around 500 research projects with funding totalling around 260 million euros since 2004. The strategic focus is placed on the efficient use of fossil fuels in power plants, as well as on technologies that enable the separation, transport, and storage of CO_2 (CCS).

An important element of COORETEC is the Advisory Council established by the BMWi. The Advisory Council consists of representatives from industry, research and politics and advises the Ministry on ongoing funding measures and new trends. In addition, the Advisory Council provides recommendations for the strategic focus of the research activities. Alongside the BMWi activities, this body observes international projects and the support provided to fundamental research by the BMBF (geotechnology programme) and gathers information on the research funding provided by the German federal states.

The Advisory Council has four working groups. These are headed jointly by one speaker from industry and one speaker from science. This demonstrates once again the desire to closely integrate theory and practice. The working groups focus, amongst other things, on technology for increasing the levels of efficiency and flexibility in power plants, gasification technologies for electricity generation and non-energetic use of coal and other fuels, technologies for CO_2 separation and technologies for the transport and storage of CO_2.

The research carried out by the turbo machinery joint venture (AG Turbo) has a cross-sector role focussing on the development of efficient turbo machines and works closely together with all four working groups in COORETEC. Regular seminars on the current status of the working groups and AG Turbo complete the project structure.

The COORETEC initiative celebrated its 10th anniversary in 2014. The occasion was marked by a celebratory symposium held by the BMWi in Berlin with 130 participants. It is also thanks to COORETEC that German power plant technologies are today considered to be world leaders in their field.

HIGHLIGHT

Clean Energy Center (CEC): climate-preserving combustion technology

More efficient, more powerful, lower emissions: these three concepts are the guiding principles behind the joint project Clean Energy Center (CEC) under the leadership of Siemens AG. Nine research institutions from the areas of power plant technology and materials sciences are participating in a total of 20 individual interdisciplinary projects. The centrepiece is the research, development and test centre for gas turbine burners that can produce electricity while preserving the environment – which was put into operation on 19 February 2015.

The highest level of efficiency for a combined power plant is currently 60.75 percent. This was recorded for a gas and steam turbine in a power plant operated by Siemens AG. In order to further increase the level of efficiency in modern combustion turbines, it is necessary to constantly improve existing technologies. The burners are an essential decisive factor in increasing the efficiency of gas power plants. The Clean Energy Center can now test prototypes for newly developed gas turbine burners under realistic conditions. The results are thus more robust than computer simulations of combustion processes. This allows the continuous reduction of operating costs for the turbines and a further reduction in the environmental impact caused by this type of energy conversion.

Overall, the CEC has three test cells available for testing combustion processes. In these cells, natural gas and heating oil are mixed in the gas turbines under great pressure and then ignited by 24 identical burners. The resulting heat and the pressurised air-gas mixture then turns the rotors in the turbines. This drives a generator to produce electricity. Scientists are able to carry out tests using these burners to investigate different parameters such as performance, efficiency, emissions and flame stability. Alongside natural gas and heating oil,

The Clean Energy Center tests environmentally friendly combustion processes in three test cells

alternative fuels such as hydrogen, ethane, propane and butane can be added to the mixtures for combustion tests. The advantage of this technology is that the gas power plants can be started and operated flexibly. However, different conditions apply to the combustion processes depending on whether the power plant is being run under partial or full load operation.

The Clean Energy Center is located in Ludwigsfelde near Berlin and has created 25 additional skilled jobs in the region. Ludwigsfelde in Brandenburg was chosen as the location because of the existing natural gas line and high-voltage electricity grid that ensured a secure supply of energy. The BMWi is funding the first two phases of the research projects around this test centre which are carried out by a consortium of industry and science with around 9.63 million euros. The project has cost around 19.26 million euros to date and is due to run until December 2016. The third phase is currently being planned.

Selected funded projects

ADECOS: component development and process optimisation for oxyfuel

The oxyfuel process is a combustion process that takes place in an atmosphere consisting of recirculated CO_2 and oxygen. The technology makes low CO_2 emission electricity generation from coal possible because it simplifies the separation of CO_2 from the exhaust gas and its further use for recycling or even storage, for example in geological formations. The optimisation of individual oxyfuel processes and components will play a decisive role in its future application in practice and at the scale of larger power plants.

This forms the focus of the ADECOS project. ADECOS stands for “Advanced Development of the Coal-fired Oxyfuel process with CO_2 Separation”. The joint project ADECOS Components is the latest and also third phase of the ADECOS oxyfuel research project. The research consortium includes the TU Hamburg-Harburg, the TU Dresden, Forschungszentrum Jülich, the Zittau/Görlitz University of Applied Sciences and the University of Stuttgart. The project is divided into three subsections. The first focuses on research into the materials used for steam generator heating surfaces in the oxyfuel process, including experiments into fouling and slagging behaviour. The second deals with gas treatment and the third subsection places a special focus on the themes of measurement technology and operation.

The ADECOS Components project could play an important role in future low emission power plants with CO_2 separation rates of up to 99 percent. Experts anticipate that there will be a market for these types of power plants from 2020. The project is part of the COORETEC initiative (see box on this theme) and was provided with 1.15 million euros of funding by the BMWi throughout the course of the project from April 2011 to March 2014. The overall cost of the project was 2.3 million euros.

PCC pilot plant for CO_2 scrubbing

The separation of climate relevant CO_2 from industrial waste gases represents a promising option for reducing greenhouse gas emissions. A research consortium including RWE Power AG, BASF SE and Linde Engineering Dresden GmbH has developed an energy-optimised CO_2 separation process for power station flue gases. It represents signifi-

PCC pilot plant for CO_2 scrubbing in Niederaußem

cant progress in comparison to currently available technology. The process is being tested by the project partners under real conditions in a brown coal power plant in Niederaußem near Cologne. The Post Combustion Capture (PCC) pilot plant started operating in July 2009 and possesses all the elements of a large-scale carbon capture plant. Meaningful results are being achieved due to this set-up and the excellent plant availability of 97 percent.

In the POSTCAP Follow-Up Project II (funding phase III), the scientists at the three companies have now been investigating further measures for improving amine scrubbing technology since March 2014 – an important step along the road to a commercial PCC technology. The project partners aim to develop a better understanding of the formation of aerosols in order to avoid possible emissions. In addition, they hope to further reduce energy needs and the consumption of scrubbing agents.

The scientists are working on further reducing CO_2 abatement costs in CCS by lowering the investment and operating costs for the separation technology. Through the positive and improved environmental balance, the aim is to also further increase social acceptance for CCS technology.

Another focus of the research is the testing and evaluation of variants of two new scrubbing agents (OASE®-Blue) and long-term testing using the optimal variants. Furthermore, the project is working on simulating gas turbine flue gases that enter the CO_2 scrubbing unit as raw gas, continuing the material testing and improving the technical, economic and ecological concepts for large-scale CO_2 scrubbing units and updating studies in large-scale plants.

Ceramic membranes for gas separation in fossil fuel power plants

Germany has set itself ambitious climate protection targets. Alongside the expansion of renewable energies, the further development of fossil fuel power stations to achieve lower emissions and greater efficiency and flexibility will also be decisive for the successful achievement of these targets.

On this basis, the consortium METPORE II is carrying out research into the separation of carbon dioxide from waste gases with the help of ceramic and polymer membranes. The project partners that include Forschungszentrum Jülich, the Helmholtz-Zentrum Geesthacht – Centre for Materials and Coastal Research GKSS, the Karlsruhe Institute of Technology (KIT), the DVGW Deutscher Verein des Gas- und Wasserfaches e.V. and the DVGW test laboratory at the Engler-Bunte-Institute are using the findings from the work carried out in the previous project METPORE I. This earlier project already saw the scientists developing ceramic metal-supported membranes for the separation of CO_2 and N_2 in waste gases from fossil fuel-fired power plant processes.

One of the aims of METPORE II is to reduce energy losses and avoid the accrual of toxic residues by using membranes for separating CO_2 instead of scrubbing. Furthermore, the membranes are expected to also offer advantages in terms of scalability and their use in partial load operation. In addition, a fully equipped test rig for membrane modules has been operated for more than 700 hours in the Rheinhafen steam power plant in Karlsruhe and CO_2 separation was demonstrated using real waste gases with membrane technology on a prototype scale. The evaluation of the results is still ongoing. The successful implementation of this technology into the megawatt range would have a decisively positive impact on environmentally friendly fossil fuel power plants.

This strategy for CO_2 separation in gas mixtures can also be utilised for other processes such as biogas processing. The METPORE II project is part of the COORETEC initiative (see box on this theme). The BMWi supported the project with 2.9 million euros of funding.

COOREFLEX-turbo: the start of a new research consortium

The second instalment of COOREFLEX-turbo – a five year research consortium under the banner of AG Turbo – started in autumn 2014. This joint venture forms the German platform for research into innovative turbo machines (see box on this theme). AG Turbo has already existed for 28 years and is dedicated to pre-competitive and application-oriented research into turbo machines. In particular, the focus is placed on steam and gas turbines, as well as on compressors. The research serves to realise combined power plants and the transport of CO_2 Turbo machines can also assume a central role in the areas of compressed air storage, hydrogen and biomass combustion, and concentrated solar power (CSP).

In the area of power plant research, AG Turbo stands out worldwide as a unique selling point for the Federal Republic of Germany and sustainably supports the leading technological and economic role held by the country. Turbo machines make a valuable contribution to the energy transition because they continue to be indispensable when it comes to efficiency and flexibility in electricity generation. In COOREFLEX-turbo, AG Turbo is pushing forward the development of power plant processes for greater conservation of resources and improved climate protection.

The joint project COOREFLEX-turbo includes a total of 107 individual projects with a total funding volume of 66 million euros, of which 33 million euros is provided by the BMWi.

The project will be implemented in three instalments. The first instalment was initiated in the middle of 2013, the second followed in autumn 2014 and the last instalment is planned for the middle of 2015. The participants in the joint project come from industry, universities and research centres. The planning stage for a joint follow-up project is currently ongoing.

Fuel cell and hydrogen technologies

Fuel cells represent an efficient technology that can generate electricity with a high level of efficiency even in small units. In their application in motor vehicles, they have made electromobility with a comparable range to conventional vehicles with a combustion engine possible. They enable the combined, highly efficient generation of electricity and heat for the supply of energy to households. And in UPS (uninterruptible power supply) systems or off-grid systems, they make quickly available and demand-based electricity generation, which is independent from the grid, possible. Fuel cells operate using hydrogen or natural gas as an energy source and consequently have zero local emissions. The production of hydrogen using electrolysis is also a good option for utilising excess electrical energy and thus represents a link to storage technologies. Therefore, fuel cells form an important building block towards the implementation of the German energy transition.

Market developments in Germany and across the world

Despite their advantages, fuel cells are still too expensive for the wider market. This is true both for stationary applications and also for mobile applications in vehicles. Their operation is thus only economically viable with the aid of funding, while there has not yet been any clear catalyst for making cost reductions. This can probably only be achieved through series production, particularly as the components are currently only manufactured and purchased in quantities that are still too small. Therefore, fuel cells have up to now only been able to conquer niche markets such as supplying energy to caravans and yachts. Only tens of thousands of these units have been sold to date.

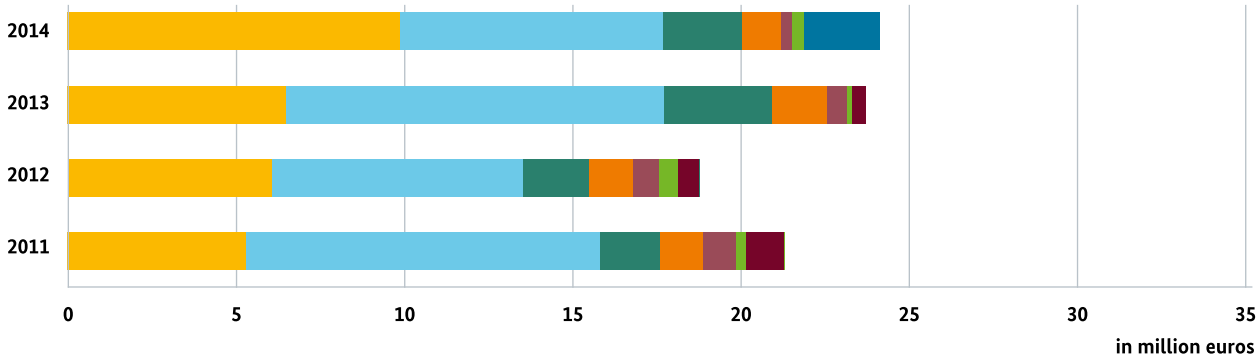
Some manufacturers in Germany have been offering fuel cell units for supplying energy to households and commercial buildings for approximately two years – and others are set to follow their lead. Corresponding programmes for launching them onto the market with a limited budget exist in the German states of North Rhine-Westphalia, Baden-Wuerttemberg and Hesse. In Japan, these household energy supply units are more widely disseminated. More than 100,000 units have been installed in the country as part of the state funded ENE-FARM programme.

According to manufacturers, fuel cells will be launched onto the German market in the automobile sector in 2017. Currently only the Renault HyKangoo is available, which uses a fuel cell to extend the range of the vehicle. In other markets, such as Japan and California, renowned Japanese and South Korean manufacturers have already announced fuel cell vehicles for 2015 and 2016 respectively.

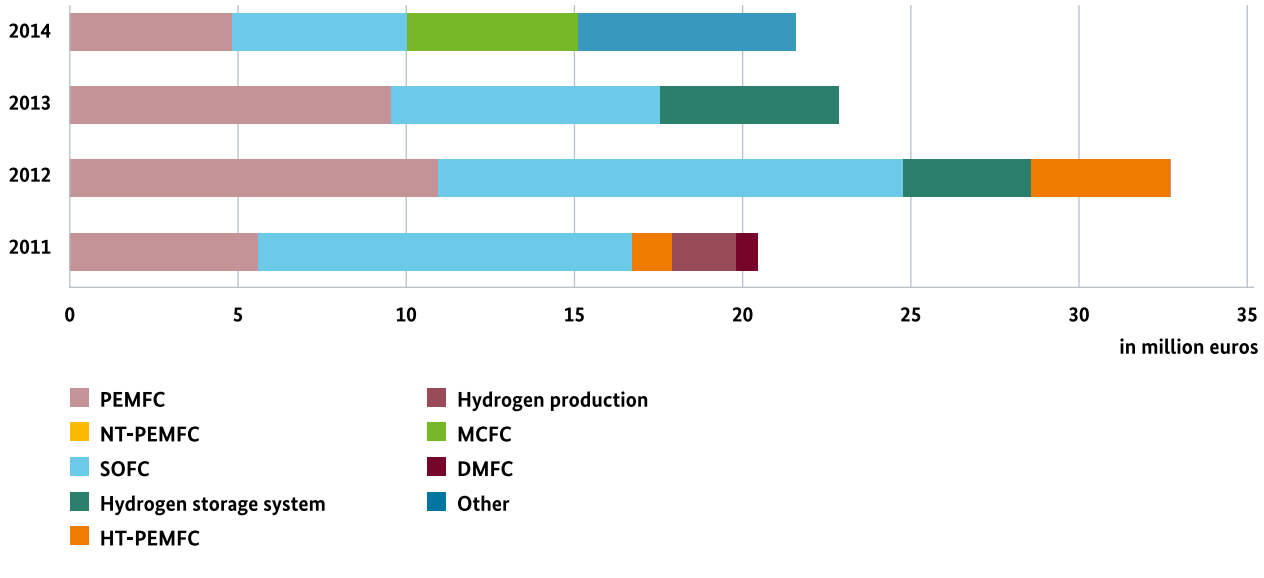
Progress in research and development

The research funding provided by the BMWi for fuel cell and hydrogen technologies forms an important component of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) initiated by the German federal government. A total of 24.1 million euros of funding was provided by the BMWi in 2014 (2013: 23.8 million euros) for a total of 112 projects. There were 28 newly approved projects with total funding of 21.5 million euros (2013: 22.9 million euros) over the entire lifetime of the projects.

Fuel cell and hydrogen technologies: Distribution of funding between 2011 and 2014



Fuel cell and hydrogen technologies: Trend in the volume of newly approved funding since 2011



Considerable advances in technology have been achieved since 2006 through the NIP funding by the BMWi and the Federal Ministry of Transport and Digital Infrastructure (BMVI). Fuel cell heating devices for supplying energy to households have been developed by several manufacturers, which have been tested in the field and fulfil the high standards required regarding their lifespan and reliability.

Some manufacturers are focussing on larger units for commercial or industrial operation for the combined generation of heat and electricity (CHP). Other fields of application for CHP systems are ships and HGVs – with both requiring power generation when stationary. In these applications, fuel cells help to reduce CO_2 and diesel particle emissions.

Fuel cell vehicles now fulfil expectations in terms of their lifespan and operation, even at low outdoor temperatures. The qualification of component manufacturers for fuel cell stacks, hydrogen filling stations and hydrogen tanks is now hugely important for industrial policy in Germany. A variety of manufacturers have announced the launch of products onto the market that have up to now been based on the use of technologies from Japan, South Korea or North America. Therefore, a clear focus of the BMWi funding is to support material and component manufacturers in Germany. The spectrum ranges from producers of materials for catalysts, membranes, bipolar plates, sealing agents for the levels in a stack and steels resistant to hydrogen embrittlement through to small parts such as pumps, valves, fans and safety sensors.

Alongside individual components, a further increase in domestic added value creation is dependent on the manufacture of complete stacks in Germany. This is why the BMWi is funding a number of joint projects to optimise cooperation between component manufacturers and which qualify companies for stack production.

In order to present the results of the projects, discuss future perspectives and send a political signal, a full meeting of all NIP participants is currently being organised for June 2015.

Strategies for research funding

The research funding provided by the BMWi and the funding of demonstrations and field tests by the BMVI complement each other constructively within the framework of the NIP. Feedback from the field tests during development and repeated field tests with new generations of equipment have led to the advances achieved since 2006 and are also required in the future to establish this technology. The development and testing of electrolysers to obtain hydrogen, for example for fuel cell vehicles, will play an increasingly important role here.

The lifetime of the NIP is limited to 2016. In order to exploit technological potential and generate products ready for market, discussions are being held to extend the programme for a further ten years. Industry experts have developed an agenda for this purpose, which includes all still unresolved issues and concrete recommendations for a roll-out programme and have presented it to policy makers.

The funding of related research and development activities by the BMWi remains an important pillar of the programme and will also focus on currently funded technologies in the future. In the process, the development of electrolysers will be afforded greater significance than it has been to date. The funding will be awarded in close cooperation with project funding in the area of storage technologies.

SPECIAL TOPIC

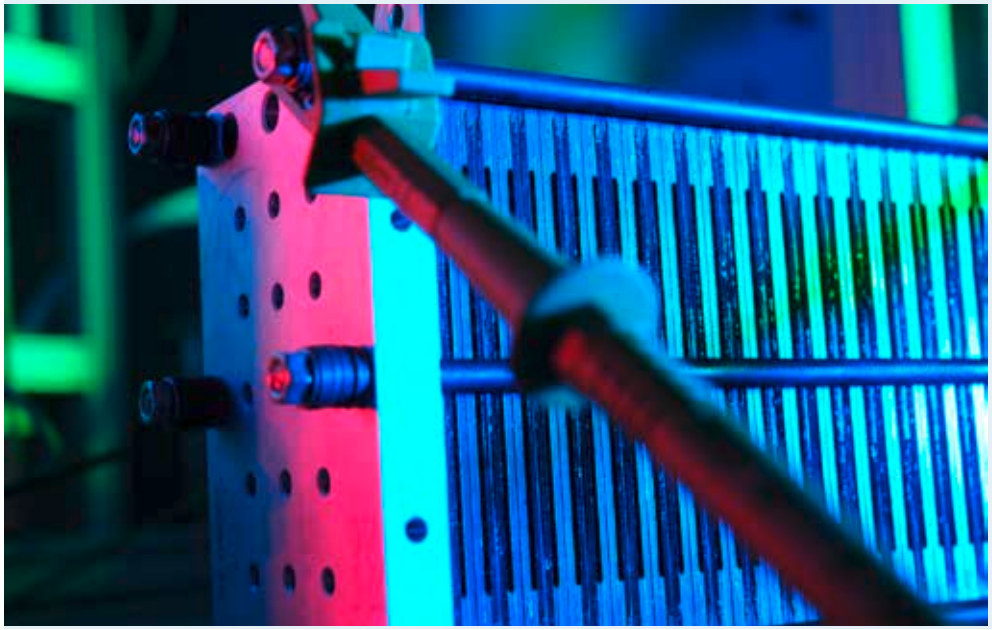
Extending the lifespan of PEM fuel cells

As a result of the growing interest in local zero emission mobility solutions, fuel cells are gaining importance as energy converters. The production of hydrogen using electrolysis allows renewable energy to be saved for use later. An important technology for the conversion of generated hydrogen is PEM fuel cells (PEM stands for Proton Exchange Membrane and describes a key component of the cells). Their advantages include a high level of efficiency and zero local emissions, as well as being comparatively noiselesswhen in operation. PEM cells work at a low temperature range of between 60 and 80 degrees Celsius. They are primarily used in transport applications but also in stationary applications such as buildings.

Research to date has already achieved great advances in fuel cell technology. Nevertheless, further developments will be required, for example regarding the lifespan of galvanised cells, before they can make a breakthrough commercially. For this purpose, a consortium including the Zentrum für BrennstoffzellenTechnik GmbH (ZBT), the Clausthal University of Technology, the ZSW Baden-Württemburg (Center for Solar Energy and Hydrogen Research), the Fraunhofer Institute for Solar Energy Systems ISE and the Technische Universität Berlin has been set up that has developed models for deriving prognoses for the lifespan of fuel cells in real applications. This should make it possible to dispense with time-consuming ageing tests in the further development of components. The Federal Ministry for Economic Affairs and Energy has provided this consortium with 2.7 million euros of funding.

The scientists involved in the consortium have programmed a software tool to predict the lifespan of fuel cells. By combining a physical-chemical model and an event-driven model, the scientists have initially been able to reconstruct the ageing behaviour of low temperature PEM fuel cells. To do this, the researchers determined experimental data about the ageing behaviour of all elements of the cells – such as the bipolar plates, seals, membranes, gas diffusion layers/electrodes, catalysers and water balance – and transferred them into the models. This should permit correct predictions to be made for a series of lifespan expectations for different fuel cells operated using different strategies. The results are subsequently used to make targeted improvements to the individual components of the galvanised cells.

The project partners have also organised multiple workshops each with two dozen participants from amongst the leading German stack, fuel cell and component manufacturers. This demonstrates the great relevance of the project for industry and has provided the project partners with practical feedback on their progress. It also helped to establish the best possible prerequisites for applying the findings from the project to the optimisation of these systems.



Test of a stack as part of the project to extend the lifespan of PEM fuel cells

HIGHLIGHT

Autonomous and uninterruptible carbon neutral power supply system

Pilot plant in Elancourt near Paris

A consortium of German and French companies and research institutions worked on the development of a reliable, autonomous and uninterruptible electricity generation and storage system for an off-grid energy supply from 2011 to December 2014 in the REnerSta (Renewable Energy Station) project. A hydrogen circuit enabled the REnerSta to supply electricity for up to ten years. The researchers focussed specifically on the development of a completely integrated yet at the same time space-saving overall solution that produced zero CO_2 emissions from renewable sources, stored the energy on-site and made it available in the short and long term.

The research consortium was coordinated by Airbus Defence and Space. This joint German-French project also included the AEG Power Solutions Group, the Artemis Group, CETH S.A., the Fraunhofer Institute for Solar Energy Systems ISE, EADS Innovation Works and SAFT Batterien GmbH.

The concept followed by the REnerSta research consortium represents a completely new approach because conventional systems are mostly backed up by diesel motors. In contrast, the REnerSta system is based entirely on renewable energies and Clean Tech applications, as well as on synergy effects through intelligent energy management. The BMWi is supporting the work of the German partners with around 1.44 million euros of funding.

The energy station is capable of covering a power demand of between one and five kW. The system is based on photovoltaic and wind power modules. The generated electricity is stored in the short term in batteries and in the long term by converting the electricity into hydrogen using an electrolyser. When output is required at a later point in time, the hydrogen is converted back into electricity in the system's fuel cells. The innovative developments in REnerSta also include the energy management system, the system design developed to be independent of location, the integrated safety technology, the electronics and the fuel cells. As a result, the overall system is flexible enough to adapt to the particular demands and conditions at the installation location. Due to the implementation of an integrated controlling solution, the entire station can be operated through effective planning in an energy efficient way.

The project participants believe that options for the possible future application of this carbon neutral power supply system include the telecommunications infrastructure, the shipping industry, signal and communication systems for road traffic or as an emergency power supply for disaster zones. This is why the researchers have also taken extreme conditions into account. The concept for the system is based on a modular design, a high level of mobility for easy transport to global deployment locations and uncomplicated installation with a low level of work required on-site. The REnerSta Power Station is designed to supply power fully autonomously (i.e. without a 230 V AC grid and without a human presence) to a telecommunications system for ten years, whereby maintenance work is only necessary once every twelve months.

Selected funded projects

Further development of PEM membranes

Making it possible to operate PEM fuel cells at higher temperatures and with lower humidification has for more than a decade been one of the options that would help this technology achieve an economic breakthrough. The use of lower quantities of precious metals in catalysts, the simplification of system components in the area of cooling and gas humidification and lowering the demand placed on the hydrogen unit would be some of the major benefits. These factors were the focus of the PSUMEA research project conducted by the Max Planck Institute for Polymer Research, the Max Planck Institute for Solid State Research and the FuMA-Tech Gesellschaft für funktionelle Membranen und Anlagentechnologie mbH. The BMWi funded this project with around 550,000 euros.

On the basis of highly sulfonated poly-phenylene sulfone, scientists have been able to develop a stable membrane with very high proton conductivity. The process involves the use of multiblock copolymers that are fabricated into membranes to form a separately arranged nano-morphology (see diagram). It is this special morphology that enables the properties for the required high level of conductivity, high chemical stability and tear resistance to be combined for use in PEM fuel cells. The novel feature is that the membrane is also created without fluorine and thus does not pose an issue during later recycling.

As part of the membrane electrode assembly (MEA), this new type of membrane has already achieved promising initial results in comparison to MEAs using currently available PFSA materials. PFSA stands for perfluorosulfonic acid, an artificially produced chemical compound. In a follow-up project, less expensive manufacturing processes are currently being developed that should make it possible to realise very thin membranes.

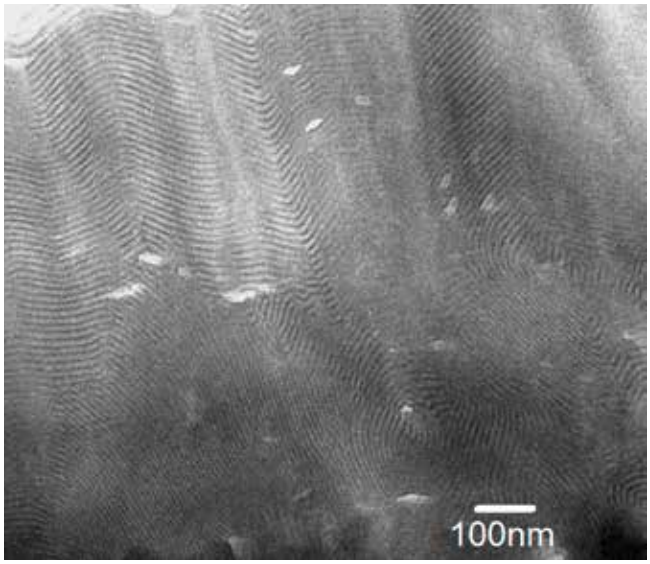
Alongside PEM fuel cells, there are other possible areas of application in the areas of energy conversion and storage (particularly for redox flow batteries).

Needs-based hydrogen production for mobile energy supply systems

Mobile phones and laptops have proved a great boost to mobility in society. Yet at the same time the need for an autonomous energy supply system has also arisen that will allow mobile phones to be charged at any time even while on the go. This is the theme behind the MetalFuel project for the development of a mobile and cost effective energy supply system using fuel cells. The focus is placed here on applications in the leisure sector.

As part of the project, scientists are working on an innovative approach for the needs-based, mobile production of hydrogen (H_2) for a fuel cell based on the electrochemical reaction between zinc and water. Advantages include the

Nano-morphology of a membrane



Hydrogen producing cells

high energy density and the low procurement cost of zinc, as well as the fact that both electrical voltages in the galvanised cells and the fuel cell are cumulative. In the process, the use of zinc pastes has enabled the researchers to solve the problem of how to guarantee the required supply of hydrogen for mobile applications for the operation of fuel cells. Software that was also developed during the project precisely coordinates the hydrogen produced by the galvanised cells and the H_2 demand of the fuel cells. Further developments in a follow-up project are still required, however, before the solution is ready for practical use and launch on the market.

The BMWi provided 2.1 million euros of funding to this joint project conducted by the Fraunhofer Institute for Reliability and Microintegration IZM, VARTA Microbattery GmbH, FLEXIVA automation & Robotik GmbH and Grillo-Werke AG.

Proof of the technical maturity of a SOFC fuel cell heating unit

In the SOFC-BZHG project, Vaillant GmbH is supporting steps to prove the technical maturity of a solid oxide fuel cell heating unit. The focus is being placed on the further development of prototypes for series production and field tests. The system is designed to enable the efficient and environmentally friendly supply of electricity and heat to detached and semi-detached houses. The units are operated using a standard household gas connection and generate 1 kW of electrical output and 2 kW of thermal output. As part of the project, the developers have been able to reduce energy demands for electricity and heating by 25 percent and at the same time halve CO_2 emissions. This makes sustainable energy provision based on the combined generation of heat and electricity possible directly at the user's premises. As the units only possess few mechanical components and use an operational management software, they are extremely robust and only require low maintenance. Another advantage for private households is the almost silent operation.

In addition, Vaillant is testing the long-term performance of two next generation prototypes and components, which were developed in previous research projects, in nationwide field tests. A further focus was placed on optimised functionality and lifespan, as well as on reducing the cost of the components such as the process gas module, electronic boards, media supply and the combination of the ignition burner and afterburner. There were also improvements in quality and operational safety. As a result of further simplifications to the systems, the micro CHP unit achieved an electrical efficiency of 30-34 percent and a total efficiency of 84-88 percent in laboratory tests. Furthermore, Vaillant successfully completed the integration and qualification of the SOFC stacks from the company sunfire into the Vaillant process gas module and also tested CFY stacks from Plansee/Fraunhofer IKTS. The BMWi supported the project with 4.6 million euros of funding.

Installation of the SOFC heating device from Vaillant

SOFC stacks and cells for mobile and stationary applications

The mobile application of solid oxide fuel cells (SOFC) is the focus of two current research projects.

The SMART project run by CeramTec GmbH, ElringKlinger AG, Sulzer Metco Woka GmbH and the European Institute for Energy Research in Karlsruhe is carrying out research

into concepts for stacks for mobile power generation and stationary applications. The stacks are based on anode substrate-supported cells (ASC). The focus was placed here on the reliability and lifespan of the stacks under a cyclical and stationary load, as well as on production and process technologies. The ASC technology offers the advantage that extremely thin membranes can be produced, which ensures that the electrolyte resistance is low and thus the output density is high. This keeps the device compact, which is an important factor especially for mobile applications. SMART received 3.9 million euros of funding from the BMWi and ended in May 2014.

On the basis of the SMART project, the ENSA III project run by Eberspächer Climate Control Systems GmbH & Co. KG, ElringKlinger AG and MAHLE Behr GmbH & Co. KG is looking more closely at the use of stacks in a complete system for the mobile sector. The focus of this project that runs until 2016 is the development of a mass-producible SOFC-APU (Auxiliary Power Unit) for providing onboard power supplies in commercial vehicles. The main emphasis is being placed on the thermo-mechanical, cyclical load on the APU, as well as optimising their functionality, lifespan and cost effectiveness. The SOFC-APU should reduce diesel consumption when at a standstill and greatly reduce harmful emissions.

The BMWi is funding ENSA III with around 15.5 million euros.

Direct methanol fuel cells (DMFC) in special markets

Liquid methanol has a high energy density and this means that direct methanol fuel cells (DMFC) have a long energy autonomy, while the infrastructure for refuelling them is comparatively easy to realise. The funding provided by the BMWi concentrates on two main fields: on the one hand, mobile DMFCs used to drive utility vehicles in buildings and, on the other hand, portable and stationary DMFCs for vehicle APUs or smaller off-grid monitoring devices. This involves low output ranges of approximately 100 to 1,000 watts in both cases.

Direct methanol fuel cells are particularly suitable for so-called special markets such as emergency power supplies, telecommunications, intralogistics, sensor and measuring technology, security and monitoring applications or lightweight electrical vehicles. This sector could play a key role in the widespread introduction of fuel cells because it will act as a pioneer for helping to establish value added chains and sales structures. One research project in this area is VERITAS, which is being conducted by the company SFC Energy AG. SFC was the first manufacturer of fuel cell systems to exceed the commercially important threshold of selling over 30,000 units.

A key technological factor is the degradation of the DMFC stacks, meaning the gradual decrease in cell voltage. The company has analysed comprehensive practical data available from the field and is using it to further develop its DMFC solution that is already available on the market. The scientists were thus able to reduce the manufacturing price by identifying cost drivers and increasing the lifespan. The BMWi has provided this research project for solutions close to launch on the market with 540,256 euros of funding.

Application of the EFOY ProEnergyBox, a complete off-grid energy solution with an integrated EFOY Pro fuel cell, fuel cartridges and batteries

Energy storage, electricity grids and the integration of renewable energies

The central challenge posed by the energy transition is the restructuring and adaptation of the existing energy supply system. Due to the decentralised expansion and input of electricity from fluctuating renewable energies, grid operators are facing new challenges. For example, they need to guarantee the security of supply on the one hand, while minimising expensive grid expansion costs on the other. Important roles within this balancing act are played by intelligent grids, the storage of electricity and heat and electromobility – which are becoming ever more important both in the area of research and development and society as a whole.

Market developments in Germany and across the world

Electricity generation from renewable energies achieved a new record in 2014: Wind, photovoltaics (PV), water, biomass and geothermal energy delivered around 157.4 billion kilowatt hours of energy – an increase of 3 percent compared to 2013. Alongside the ecological and increasingly economic advantages – such as lower amounts of delivery costs for bulk purchasers – the growth in renewable energies (RE) is also accompanied by new challenges. The electricity grid was previously designed for the central provision of consumers via conventional power plants such as coal, gas and nuclear power plants. In contrast, the expansion of PV power plants and wind turbines – which account for most of the renewable power plants – is taking place in a decentralised manner. In addition, there is the problem that the electricity generated by these power plants fluctuates depending on the weather. This has forced grid operators to increasingly turn to regulatory interventions in order to guarantee the security of supply. In future, it will be necessary to fall back on these interventions to an increasing extent even when it comes to the expansion and restructuring of the electricity grid.

The German electricity grid was 1.8 million kilometres long in 2014, yet only 130,000 km was accounted for by so-called high voltage or transmission grids that are operated for the transmission of high voltages of 230,000 volts over wide geographical areas. As part of the expansion and strengthening of the German transmission grid, the Network Development Plan envisages the addition of many thousands

of kilometres by 2030 at an anticipated cost of up to 16 billion euros. Investment in the subordinate distribution grid is anticipated to total 11 billion euros over the same period. The distances that need to be covered here are shorter and the voltage at which they are operated is lower. Alongside expansion, restructuring of the grid is also necessary. While the expansion of the grid is understood to mean the laying of additional lines, the restructuring of the grid comprises a number of individual measures. This includes, amongst other things, controlling the grid more intelligently with the aid of new communication technology. Generation and consumption will be continuously matched within these so-called Smart Grids.

Storage systems will begin to play an increasingly important role in this load management. For example, an increasing proportion of electric vehicles whose batteries are managed with an intelligent charging and discharging system could ease the burden on the electricity grid. At approximately 24,000, the number of approved battery-powered vehicles in Germany is, however, still currently too low.

In addition, existing bottlenecks in the European grid system need to be resolved in the future. Around 100 of these bottlenecks have currently been identified in the distribution grid. The required investment within the next 10 years totals 150 billion euros. In comparison, additional investment measures totalling 612 billion euros are anticipated in the USA. In contrast, the Chinese state grid operator invested over 50 billion euros in the electricity supply system in 2014.

While the expansion of the grids in Germany and Europe will enable a better geographical coordination between electricity generation and demand, storage technologies offer the opportunity of temporally decoupling them from one another. Renewable energies always feed electrical energy into the electricity grid at a high output when the sun is shining and the wind is blowing. However, this does not happen often during times of high consumption, which in Germany fluctuates between 40 and 80 gigawatts. The use of electricity storage or storage systems for energy sourced from electrical energy using conversion technologies, could enable better coverage of this load profile.

As there are no binding goals for storage stated in the Network Development Plan, any large-scale implementation of storage systems can only be expected when the costs for storage can be covered by the achievable yields from system services, or other drivers such as incentives for the creation of a hydrogen infrastructure for fuel cell vehicles materialise.

The storage of electrical energy has to date been managed primarily in pumped-storage power plants worldwide. In Germany, there is around 7 gigawatts of electrical output installed in pumped-storage power plants with a capacity of 40 gigawatt hours. In addition, there is a compressed air energy storage plant in Huntorf in Lower Saxony that has an electrical output of 321 megawatts.

As a result of the successes achieved in the development of battery technology in the last few years, the spotlight has also been turned onto this as a further option for energy storage. The world's first commercial battery power station started operating in Schwerin in 2014. At the technical heart of this plant, which is about the size of a sports hall, lie 25,600 lithium- manganese-oxide cells. Due to the speed at which they can be deployed, in the range of a few milliseconds, they can be used to stabilise grid frequency and thus deliver system services.

PV home storage systems represent another field of application. The price for solar electricity storage fell by 25 percent between the first and second half of 2014 due to technical advances and increasing demand. 15,000 households can already cover their electricity demands in the evening hours with self-generated solar energy to a significant extent. Furthermore, the burden on the grids is noticeably relieved during those hours in which the most solar electricity is generated.

Progress in research and development

In the area of grid technology, some of the technologies funded in previous years have now reached market maturity. One example are controllable local grid transformers that allow the voltage within a local grid to be kept stable when, amongst other things, there are higher feed-ins from PV power plants. Against the background of an increasingly decentralised supply of electricity from renewable energies, this will help to reduce grid expansion costs.

Furthermore, advances have also been achieved in the areas of communications and the intelligent control between the electricity generator and the grid operator. This will

enable individual renewable generation systems to be combined into a consortium to form a so-called virtual power plant. The generation and provision of electricity from renewable energies in these types of renewable combined power stations is less dependent on the weather. However, the technology required for the operation of this type of power plant still needs to be improved in many areas, for example the speed and security of the communication systems.

Planning tools for managing grid operations and the expansion or restructuring of the grids have also been developed further. Such solutions still need to be investigated in more detail in practice, however, because they can open up new possibilities for optimisations in different areas – depending on whether the focus is placed on, for example, the adequate feed-in of renewable energies, optimised economical savings or increased flexibility in the expansion scenarios. A strategic discussion on the subject "Systems analysis in energy research" was held at the beginning of December 2014. It was intended to act as the starting point for a joint, coordinated approach in the area of model-based calculations and simulations in energy research. As a result of this strategic discussion, the BMWi has commissioned Project Management Jülich (PtJ) with the first step of creating a research network for energy systems analysis. The research network will coordinate the activities in the area of systems analysis in order to exploit synergies and develop a joint strategy. An expert workshop for the research network for energy systems analysis is planned for 2015.

The conversion of electricity into hydrogen through electrolysers (power-to-hydrogen) and the further conversion into methane (power-to-gas) or higher hydrocarbons acts as a bridge between the different sectors in the energy industry. Electrochemical reactions take place in the electrolysers and produce, for example, hydrogen. As long as the electrolysers in the power-to-hydrogen plants utilise surplus electricity, they provide negative balancing energy for the electricity market. This places high demands on the flexibility of power plants. If the hydrogen is not subsequently converted back into electricity, the process then has the potential to make a contribution to the significant increase in the proportion of renewable energies in the transport sector. A particularly flexible power plant with innovative electrolyser technology is currently being constructed at the Energiepark Mainz (see page 74). Linking the power plant to a hydrogen filling station is planned in a later phase of the project.

Despite these previous advances, further research activities and developments are still required into power-to-gas technology – including power-to-hydrogen technology and batteries and their use in the distribution grid or in home storage systems.

In the case of compressed air storage systems, research is focussing on comparatively small, decentralised concepts that can store and utilise the heat energy that results from the compression of the air to a certain extent.

The integration of thermal storage systems into the electricity grid is particularly important because they help to relieve the burden on the electricity grid at peak times. This is made possible due to the potential that thermal storage systems have to achieve higher storage densities, while at the same time being cost efficient. This area also includes ideas about power-to-heat and the integration of thermal storage systems into power plants.

Strategy for research funding

With regards to the key goal of the German federal government's energy concept – increasing the proportion of total energy consumption accounted for by renewable energies – the described advances in the area of energy storage and electricity grids are not yet sufficient. The high complexity

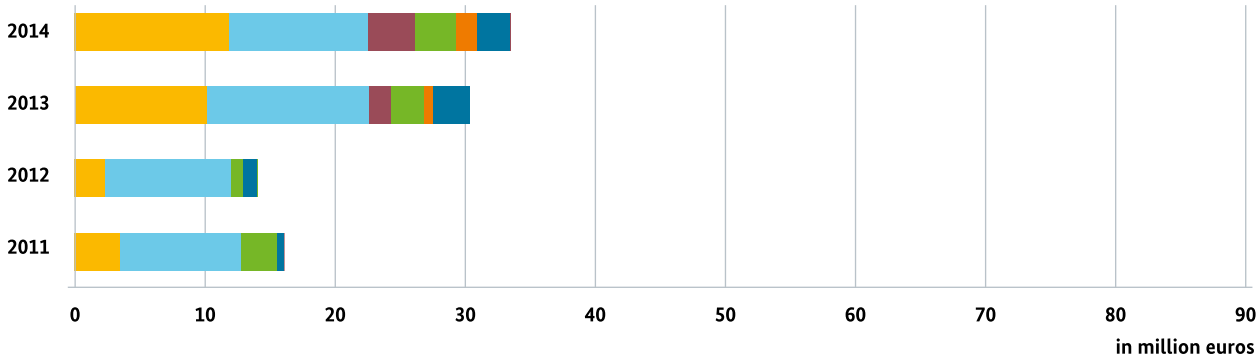
of the future energy system will have to be accounted for to an even greater extent than before within the research funding strategy. The main focus will be interlinking components, which for the most part have been individually developed, across different technologies into one complete system. The further development and integration of new information and communication technologies, issues of system security and system reliability as well as public acceptance hold positions of central importance in this area.

Therefore, funding will be provided to projects that carry out research into particularly efficient energy storage systems, offering the perspective of different storage options being available at a low cost. The same is also true for the strategy for funding in the area of electricity grids. The increasing integration of renewable energies into the grids means that the following funding priorities are necessary: modernisation of the distribution grid, developments in the area of high voltage direct current transmission (HVDC) and increasing the stability of the grid.

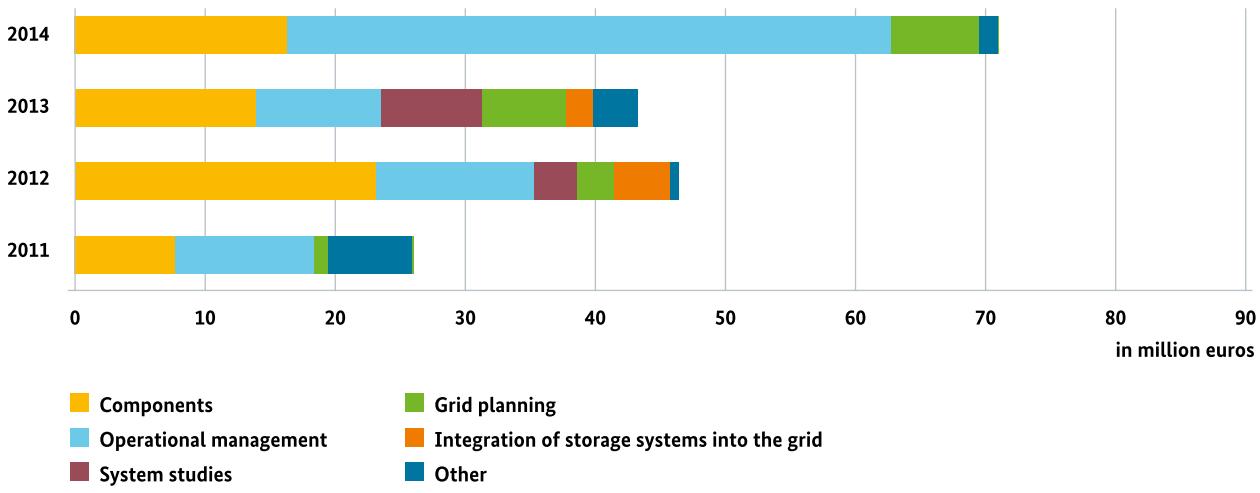
In addition, an important goal for research and development in future in the area of system integration will be the unification of existing solutions across system boundaries. Combining different supply grids such as gas, heat, water and traffic could thus create significant possibilities for greater flexibility within the energy system.

The BMWi and the Federal Ministry of Education and Research (BMBF) are conducting two research initiatives

Electricity grids: Distribution of funding between 2011 and 2014



Energy storage: Trend in the volume of newly approved funding since 2011

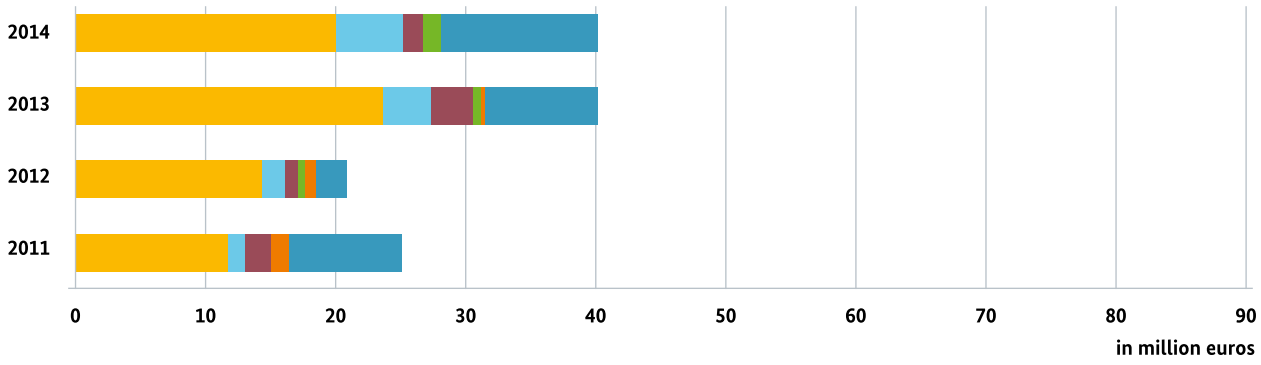


along the two central themes of grids and storage. The cross-departmental initiative “Energy storage” is dedicated to the further development of batteries and the conversion of fluctuating energy supplies into renewable hydrogen or methane and their storage (see page 73). The themes of intelligent distribution grids, transmission grids and grid regulation processes and system services are the main focus of the “Future-Oriented Electricity Grids” funding initiative.

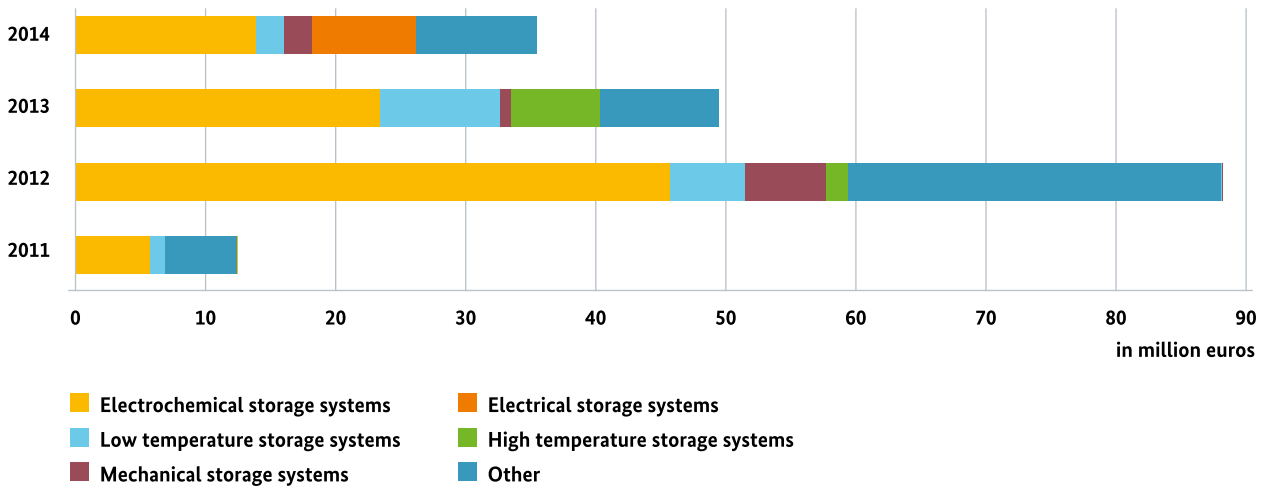
The strategy for further promoting electromobility through energy research funding is based on the research agenda of the National Platform for Electromobility. The latest status report was published in December 2014 and demonstrates, amongst other things, the need for further research funding to develop advanced cell chemistry and production methods in order to make Germany a leading international supplier in the area of electromobility.

Overall, the BMWi granted new funding in 2014 for 209 projects with a total volume of around 106.4 million euros in the area of storage, grids and the system integration of renewable energies. This underlines the ever greater importance of these themes for the achievement of the energy transition. The funding provided in 2014 totalled 73.4 million euros.

Energy storage: Distribution of funding between 2011 and 2014



Energy storage: Trend in the volume of newly approved funding since 2011



Energy storage: electricity storage systems

SPECIAL TOPIC

Storage technologies of the future

Efficient storage systems are required in order to compensate for the strong fluctuations in the supply of electricity from renewable energies. The available capacities and the technological possibilities are, however, not yet sufficient. Many storage technologies are too expensive. Therefore, the German federal government initiated the cross-departmental research initiative "Energy storage" in summer 2012. More than 250 research projects are dedicated to the further development of energy storage and its integration into the existing system of grids, power plants and consumers.

The Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of Education and Research (BMBF) have made funding totalling 188.9 million euros available for this initiative. The BMWi has funded 191 projects with around 114.1 million euros (as of 31 December 2014).

The projects involve researchers from both science and industry working closely together. Alongside batteries, capacitors and flow storage, the range of themes also covers compressed air and hydrogen storage and the associated electrolysers. In the area of thermal storage, research ranges from latent heat accumulators and sorption storage units through to the integration of heat storage into the heating grid.

The conversion of surplus electricity into hydrogen and the use of batteries in stationary power plants are key themes in this area – which is why the funding projects in the areas of "Combined Wind-Hydrogen" and "Batteries in Distribution Grids" (known as flagship projects) were organised.

The portal forschung-energiespeicher.info provides comprehensive information on the goals and results of the projects. There is a clear overview of each individual project that gives the key data with detailed information on the goals, intermediate results and approach being followed. This service is supplemented by up-to-date news, interviews, diagrams and portraits. The portal is designed both for experts and also for anyone interested in these specialist fields

Alkaline electrolyzer stack: The scientists of the project "PlanDelyKaD", coordinated by the DLR, studied the theoretical conditions for testing an integrated system of "Electricity, hydrogen, large-scale storage and usage" on a scale relevant to the energy industry

The intermediate results of the storage initiative will be presented at a two-day status seminar in April 2015. This networking meeting organised by the BMWi will illustrate the role of energy storage in the energy system of the future and provide information on the current status of international research. In addition, concrete results and intermediate results from the individual research projects will be presented in parallel sessions.

Thanks to this research initiative, it has been possible to further develop a broad range of storage technology for electricity, heat and other energy sources.

SPECIAL TOPIC

Power-to-gas in the Energiepark Mainz: the world's largest hydrogen energy storage plant with PEM electrolysis relieves the burden on the electricity grid

The keynote of the success of the energy transition is the possibility of being able to store energy generated by renewable energies on a large scale. In this context, power-to-gas represents an interesting option for storing electricity from wind or solar power plants in the form of hydrogen or methane. Power-to-gas should thus reduce the current practice of switching off wind and PV power plants in the event of an overload of the electricity grid because the electrical output from renewable energies can be utilised for the electrolytic production of hydrogen.

Scientists and engineers from Stadtwerke Mainz AG, Siemens AG, Linde AG and the RheinMain University of Applied Sciences have been working on the development, testing and utilisation of this process for a large output class application in the joint project Energiepark Mainz. The aim of this major project is to be able to store the electrical energy generated by renewable energies in chemical form by breaking down water into hydrogen and oxygen and making it available when it is needed at a later point in time. Renewable energies could thus be flexibly utilised at precisely the time that they are required. Overall, the planned system should be capable of taking over six megawatts of electricity from the grid and will thus be the world's largest power-to-gas energy storage system based on PEM electrolysis technology (PEM: Proton Exchange Membrane) to date. This also means that the system will be of such a size that it can compensate for bottlenecks in the distribution grid.

The project is testing all the options available for integrating volatile renewable energies both energetically and materially into the existing grid system for energy generation. One of the goals of the project is to develop an optimised operating concept as a result. A new type of hydrogen electrolyser will form one central element of the planned large-scale storage system. It uses three PEM-based pressure electrolysers, each with up to two megawatts of input. PEM electrolysis systems have so far only been utilised for the production of small quantities of hydrogen. The hydrogen is subsequently compressed by an ionic compressor into storage tanks. The new type of compressor is highly efficient and can be dynamically operated just like the PEM electrolysis system. The hydrogen is then fed into the natural gas grid from the storage tank to subsequently generate electricity and heat, or it can be further compressed and stored in H_2 tankers for delivery to the growing network of hydrogen filling stations.

The foundation stone was laid by the Federal Minister for Economic Affairs and Energy Sigmar Gabriel on 15 May 2014. This innovative research system is due to start operating in the middle of 2015. The realisation of the project will cost approx. 17 million euros. The BMWi is supporting this project for the environmentally friendly production of "green" hydrogen with 8.9 million euros of funding as part of the "Energy storage" research initiative.

Laying of the foundation stone by the Federal Minister for Economic Affairs and Energy Sigmar Gabriel

Energy storage: thermal storage

Selected funded projects

Mobile sorption storage units for utilising waste industrial heat

Due to its high temperature, waste industrial heat represents an extremely promising energy source for other processes. However, this heat is mostly unused and discharged into the environment because the possibilities for local utilisation do not exist on-site. For this reason, ZAE Bayern in cooperation with Hoffmeier Industrieanlagen GmbH has developed a mobile heat storage system based on an open sorption process. This joint project was funded by the BMWi with around 1.7 million euros.

Particularly high demands are placed on such a storage system because it will need to be moved several times in its lifetime and the materials must be able to withstand high temperatures. The solution here was a thermochemical storage system with a fixed bed filled with zeolite. This is mounted on a container swap body and transported on a semi-trailer. In demonstration tests, it was possible to achieve an average gas saving of 3.7 MWh per container and cycle.

Hot air flows through the storage system while charging. This drives water in the form of steam out of the zeolite. The energy required for the desorption remains loss-free in the dry zeolite and can be maintained for a limitless period. Cool damp air then flows through the storage system for discharging. The humidity in the air is thus adsorbed by the zeolite. The air is then heated by the released adsorption heat. This very dry and hot air transfers its heat in turn during a downstream process where it can additionally absorb moisture again.

A demonstration plant with two mobile storage systems was constructed in Hamm in North Rhine-Westphalia as part of the project. It was used to conduct practical tests of the overall concept. The waste heat supplies the incineration plant in Hamm and the drying process takes place eight kilometres from the plant at the company Jäckering in a plastic processing plant.

EnOB: The use of phase change materials (PCM) in the building sector

Construction systems with integrated phase change materials (PCM) enable the temperature-controlled storage of heat and thus allow for the energy efficient regulation of temperatures in rooms. The gain in efficiency results from the fact that PCM can cap high temperature fluctuations and thus reduce the need for mechanical air-conditioning systems. In order to accelerate the launch of energy efficient solutions such as PCM onto the market, practical demonstrations of these innovations are very important, particularly in the building sector. For this reason, a joint project was started in July 2014, which has eight partners from the areas of industry and research and is coordinated by ZAE Bayern, and which is dedicated to this subject. The aim of the research project – which has received 5.4 million euros in funding from the BMWi – is to investigate and evaluate the use of phase change materials in different applications in the building sector.

The focus is being placed on monitoring different PCM systems under realistic conditions in reference buildings for the relevant application. The project is following a dynamic approach in which new developments in the area of PCM materials and PCM encapsulation can also be included that arise during the term of the project. As a result of the integration of corresponding measurement technology, scientists can monitor the behaviour of the solutions over a long period of time.

Another focus is the validation of existing simulation software that is being used as part of the project. The aim here is to make the effects of PCM and the requirements that must be met by building components and systems with PCM components easier to calculate for practical application.

The project partners aim to subsequently use the results of the project for optimising the phase change materials and building systems used.

Salt-impregnated zeolites from the EnErChem research project

HIGHLIGHT

A globally unique hybrid battery storage system with 5 megawatts of output

In view of the integration of ever increasing proportions of renewable energies into the electricity grid, stationary storage systems for energy and load management are constantly gaining in importance because they provide stability. A globally unique hybrid battery storage system with a power output of five megawatts is currently being constructed in Aachen. The findings from the project should help to push forward the integration of renewable energies, the use of storage system in grids and the cost evaluation of stationary storage systems.

As part of the **M5BAT** (Modular Multi-Megawatt Multi-Technology Medium-Voltage Battery Storage) research project, scientists who come from each of the five partners are conducting research into large-scale battery storage systems with the focus on – and this is the special feature of the project – the modular linkage of different battery technologies. Here, lithium-ion batteries are being utilised as short-term high performance storage systems. High temperature batteries should then provide energy for around two hours. Finally, lead batteries with a medium discharge time of around one hour will then be used. This will enable the storage system to cater for different requirements at the same time.

The spotlight is being placed on the integration of renewable energies. The consortium is thus striving to achieve the structural scalability of the storage system. In addition, the regulated decentralised supply of power to stabilise grid operations is being tested and the effects of trading the energy to exploit price differences for electricity is being observed. The operation of M5BAT, the integration of the system into the grid and the scientific support for the project are all being provided by the E.ON Energy Research Center at RWTH Aachen University. E.ON is responsible for both the planning and the construction of the battery storage plant and for the development and testing of the marketing strategies for future products on the energy market.

The performance class of five megawatts of electrical output and the high degree of modularity are what make M5BAT globally unique. Storage systems of this scope are essential for the success of the energy transition because they relieve the burden on the electricity grid and help to adapt supply to demand. Due to their lack of dependence on geographical conditions, battery storage systems provide a decentralised solution that can be flexibly utilised at the site where energy is generated or converted. There are thus a broad spectrum of potential fields of application.

The BMWi has provided funding of around 6.5 million euros for this project since it was started in the summer of 2013 as part of the “Energy storage” research initiative. The most important milestone to date – the start of construction of the large-scale storage system – will take place at the end of 2015 in Aachen following comprehensive preparation work.

Simulation of the large-scale storage system M5BAT

Energy storage: electromobility

Selected funded projects

High energy lithium batteries for the next generation of electromobility

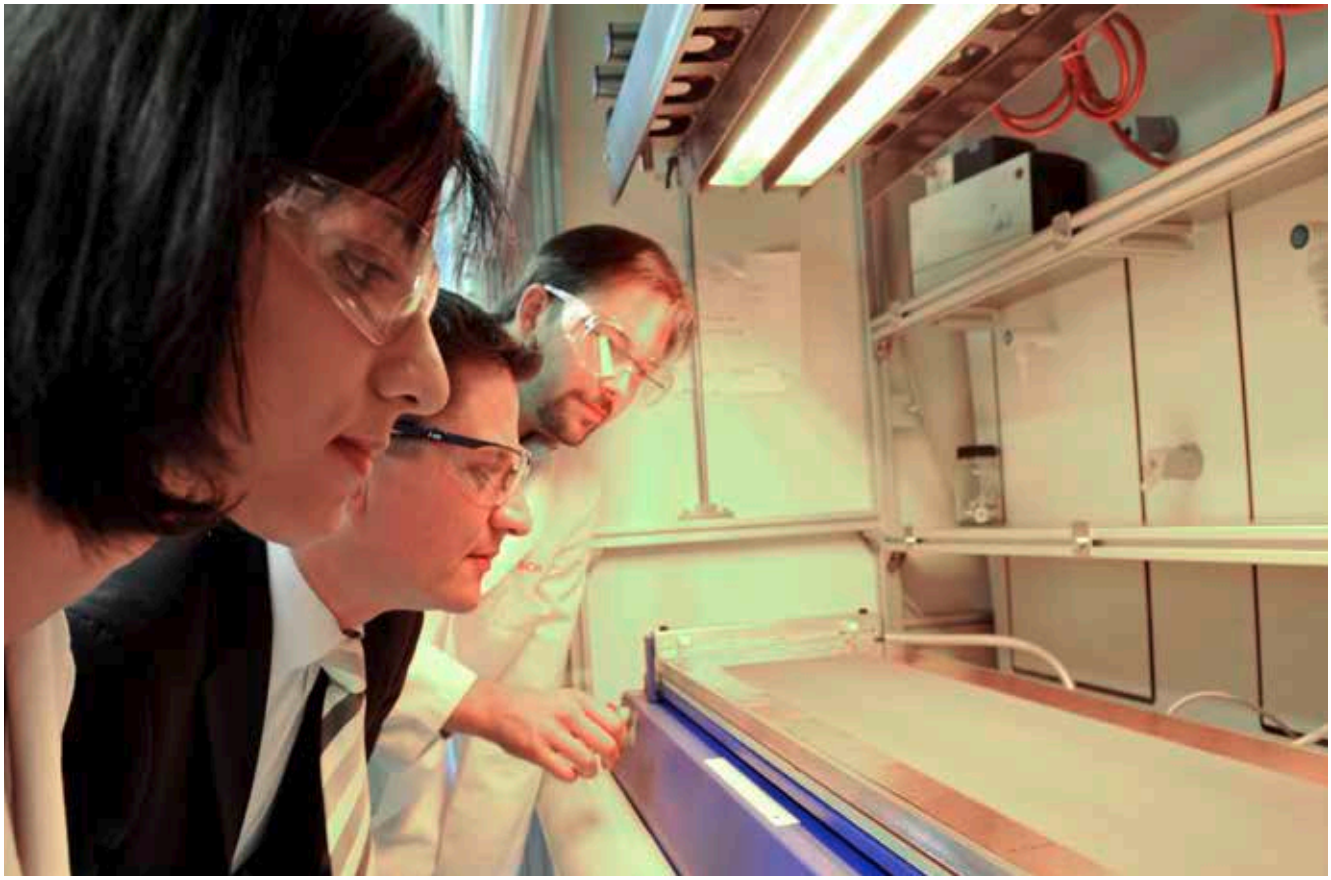
Electromobility will form an important component of an environmentally friendly mobile future. Yet there needs to be more progress made to make this form of transport marketable and to make it usable over larger distances.

In the **alpha-Laion** joint project, scientists are developing traction batteries for electric vehicles with a particularly high energy density of over 250 Wh/kg. From the basic materials and cells through to the stack and batteries, the aim is to markedly improve the entire system for automobile applications. Initially, the scientists want to further develop a lithium-ion technology suitable for the mass market and at the same time conduct research into batteries for the next and subsequent generations. The project partners aim to use the high energy traction batteries to increase the range of compact electric cars to around 300 kilometres. Users will thus be more independent of charging stations so that they can remain mobile for longer.

Another step in this process is the development of innovative materials for cathodes, anodes and electrolytes that are stable at high voltages. These battery elements will create a new electrochemical system for use in a lithium-ion cell whose design will be adapted for the newly developed materials. The aim is thus to optimally utilise its storage characteristics and make long-term durability possible.

The industry consortium alpha-Laion comprises the following companies: Robert Bosch GmbH, BASF SE, SGL CARBON GmbH, Wacker Chemie AG and the automobile manufacturers BMW AG and Daimler AG. The BMWi is providing this project that runs until the autumn of 2015 with 12.9 million euros. In a complementary project, Robert Bosch GmbH is focusing on optimising the technical processes in the production of lithium-ion batteries in order to prepare them for series production in automobile applications.

Alpha-Laion project coordinator Dr. Ralf Liedtke, Robert Bosch GmbH (centre)



SPECIAL TOPIC

"It is not sufficient to have a technically superior cell, it also needs to be economically superior"

The battery is a decisive component for marketable electromobility. What are the most promising types of battery cells that could be successfully developed for launch onto the market?
Schreiber: At the moment – and also in the near future – battery cells made of nickel cobalt manganese oxide (NMC) are being utilised. Asian manufacturers are currently supplying these types of battery cells. They are available in two different designs or housing types, either with a hard case or as pouch cells. The advantages offered by the hard case cells are that it is possible to mechanically compensate for the change in volume due to the cell chemistry, they are very stable and there is already a very good amount of experience with regard to their application. The disadvantage is their heavier weight. Pouch cells can be constructed in smaller and more flexible forms. Therefore, the strategic trend is heading in the direction of pouch cells in order to exploit these advantages. However, there is still a need for some more research work so that they will be able to match the safety levels and characteristics of the hard case cells.

What are the greatest challenges currently?
Schreiber: One major issue is cycle stability. We currently assume that for purely electric vehicles a cell will be charged and discharged 3,000 times, after which it must still have a minimum of 80 percent residual capacity. The requirements for plug-in and hybrid vehicles are even higher. The challenge here is the raise the number to 6,000 or potentially even 10,000 cycles. This will not prove easy. In parallel, it is necessary to increase the calendar life of the cells. Although we currently assume that the cells will last for 10 years, there is still no comprehensive experience with them and a lifespan of 15 years is the goal. An increase in the energy density is here a major challenge. It still remains very low in comparison to normal fuel. At the same time, it is naturally important to maintain safety. And last but not least, there is still a need to reduce costs further. The costs are still very high and one of the main reasons why the dissemination of electromobility – and also stationary energy storage systems – has not yet reached the levels that we envisage.

Prof. Dr. Werner Schreiber, Managing Director of VOLKSWAGEN VARTA Microbattery Forschungsgesellschaft mbH & Co KG

You have already concluded two research projects in this area in 2014 with Li-FeM and Li-NaS. What were the most important results?
Schreiber: Both projects dealt with research into lithium-ion cells. In the Li-NaS project, we carried out research into the cell chemistry in order to further increase the energy density. But this was not the only aim. The Li-FeM project conducted research into manufacturing methods because we recognised that the composition and design of a cell, as well as the manufacturing process, were strongly influenced by and dependent on one another. During the four year life of the project, we were able to manufacture a cell from scratch that outperformed the competition. We were able to achieve 170 watt hours per kilogram with this cell. Our aims were to verify the manufacturing costs for this type of cell within the framework of a business plan and demonstrate that they stood at 200 euros per kilowatt hour. We also managed to achieve this. In parallel, we carried out research into and further developed the manufacturing process.

In the LiMO project that began at the end of 2014, you are striving to develop the third generation of batteries. What are the concrete goals?
Schreiber: Certain limits have been reached with the types of cell chemistry using NMC materials. In order to further increase energy density and also performance, we are conducting research into other cell chemistry systems. We are attempting to produce two cell variants

and then optimise them according to their type of application. We want to investigate high energy cells in order to increase their energy density from 170 to 280 watt hours per kilogram. In the case of high performance cells, we want to maintain their energy density but increase their performance density from 1,000 to 2,200 watts per kilogram.

What role does the cost of raw materials play?
Schreiber: Materials are clearly the main cost driver in the manufacture of cells and also for research. Approximately 60 to 70 percent of the costs of a battery cell are due to the materials. Furthermore, auxiliary materials such as aluminium and copper foil are very expensive because they must be fine and highly precise and manufactured to within a tolerance of one micrometre. It is only when we have reduced the costs and at the same time achieved our technical goals that we will become competitive. It is not sufficient to have a technically superior cell, it also needs to be economically competitive.

What are the prospects of series production in Germany?
Schreiber: The trend in Germany is currently moving towards battery production. That means that different companies are focussing on this goal and producing machines for the manufacture of battery cells. This has boosted developments in this area. On the other hand, location alone is not enough to guarantee the market. Germany is in clear competition with Asian suppliers when it comes to current battery cells. Achieving the economic targets set by the competition will be a major challenge.

Electricity grids

SPECIAL TOPIC

Intelligently assembling the building blocks

The energy transition can only succeed with an intelligently designed and operated grid that safeguards the quality of the electricity supply even with high proportions of renewable energies. Science and industry are jointly developing intelligent management and control mechanisms to optimally integrate electricity from photovoltaic and wind energy plants into the grid.

Prof. Dr. Martin Braun is Head of the "Department of Energy Management and Power System Operation (e^2n)" at the University of Kassel and Head of the Department "Distribution System Operation" at Fraunhofer IWES

What influence has the energy transition had on the electricity grid?
Braun: In order to ensure the energy transition could gain momentum, the focus was placed on installing renewable energy power plants so that they could quickly make a contribution to the energy supply. Photovoltaic and wind power plants have now become major pillars of our energy supply system. Therefore, they need system services in order to deliver the required contribution to the stability and efficiency of the entire system.
The energy transition has resulted in new resources such as power inverters and millions of active decentralised plants that are often operated based on the weather conditions. How they are used in future grid structures and within an all-encompassing and sophisticated control concept are important issues. We want to combat these challenges with intelligent solutions.

What could intelligent networking look like?
Braun: Intelligence is possible at different points within a technical system: both in the control and the design of the system. A relatively inexpensive measure is to control the performance of local system components depending on the voltage, such as inverters in photovoltaic plants. They ensure that the required reactive power for the plants is supplied at the connection point or the effective feed-in power is reduced in situations critical for the grid. A smart control system can help to maintain voltage limits and reduce the burden on the grid.
However, intelligent networking also means integrating different actors through the means of IT and coordinating their interactions within the entire system. This involves linking the different levels of the energy system with one another, for example the distribution grid, transmission grid, virtual power plants and building energy management. Many of the building blocks for creating intelligent grids already exist. The most important task in the future is to intelligently use and coordinate these building blocks so that they function together in combination.
Based on the three criteria of security of supply, environmental compatibility and economic efficiency, we are examining the entire structure of the energy supply system and investigating where intelligent networking is sensible and necessary and where it is not.

How are you proceeding in concrete terms?
Braun: In close cooperation with industry, we are developing, for example, a testing and simulation environment for future electricity grids. This platform can be used by grid operators and energy traders to test intelligent management and control mechanisms and their interplay in the transmission and distribution grids under realistic conditions – all in real-time. Our industry partners can then dock directly into this virtual environment with their operational management systems.
We utilise the simulation environment as a development and test platform for actually operating management systems that will also be used in field tests. In future, we want to make year-long simulations possible so that a macroeconomic evaluation of the different operation management models will be possible. This would enable us to develop solutions that would make a significant reduction in the costs for the expansion of the grids.
And we will be creating a system that guarantees a high level of security of supply, in combination with a high proportion of renewable energy power plants.

Selected funded projects

Optimal interaction in the distribution grid

Due to the increasing expansion of renewable energies, the medium and low voltage distribution grid is approaching its capacity limits, especially in rural regions. The results are problems with voltage stability and overloading of resources.

A consortium consisting of a broad range of members from the areas of industry and science under the coordination of the Technischen Universität München (TUM) and the Technischen Hochschule (TH) Nürnberg is conducting research into improving the capacity and security of grid quality in distribution grids in the "Verteilnetz 2020" (Distribution Grid 2020) project. The project partners aim to develop many different kinds of previously unavailable resources and integrate them into the distribution grid.

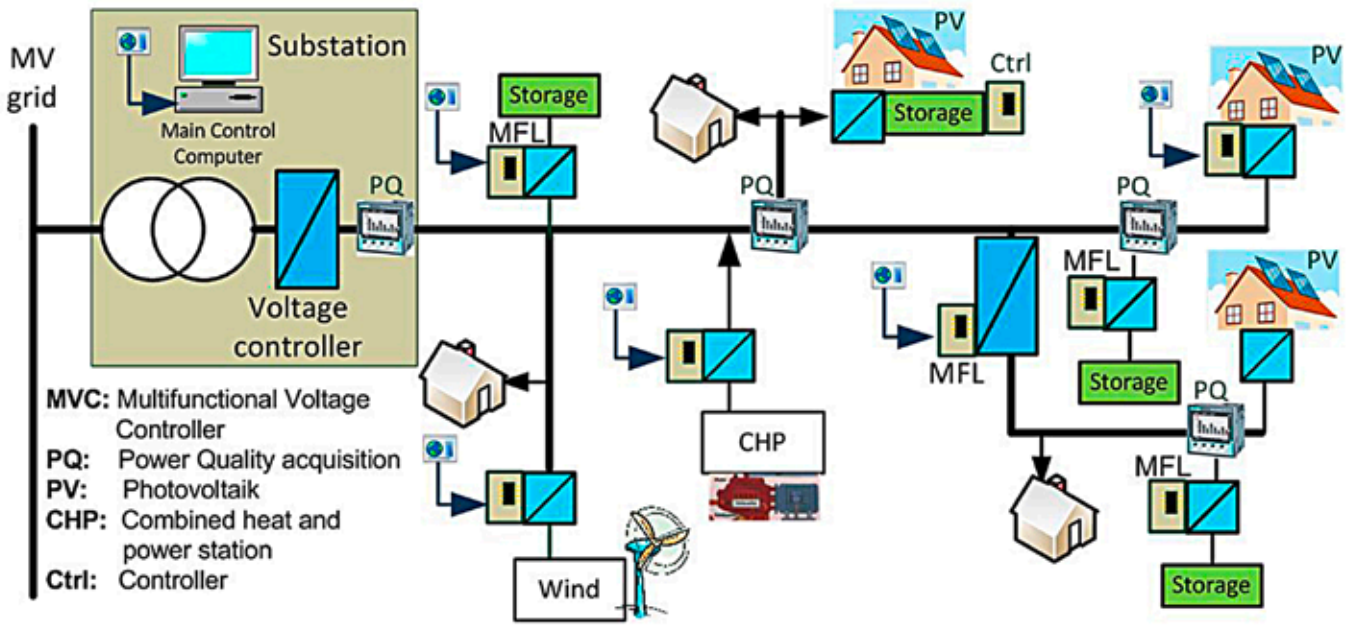
These innovative resources include, on the one hand, controllable and adjustable feeders and inverters that can stabilise the voltage or control the effective and reactive power through their advanced functionality. On the other hand, the researchers aim to develop controllable, decentralised electricity storage systems that can be operated in an optimal cycle based on forecasts of consumption and generation. In this way, they want to achieve a longer service life and thus more economic modes of operation for the storage systems. Other innovative resources include intelligent, controllable and multi-functional linear regulators that can, amongst other things, compensate for grid disturbances and stabilise the voltage as line regulators in local grid stations.

The project partners want to integrate these different resources into an overarching, automated control system using a communication system. Control technology should ensure the optimal interaction of the resources.

The scientists will initially simulate how the different types of resources interact with one another and then study this simulation in a laboratory test. Based on the results, they then want to conduct a field test of the entire system in the distribution grid of the participating grid operator – Infra Fürth GmbH.

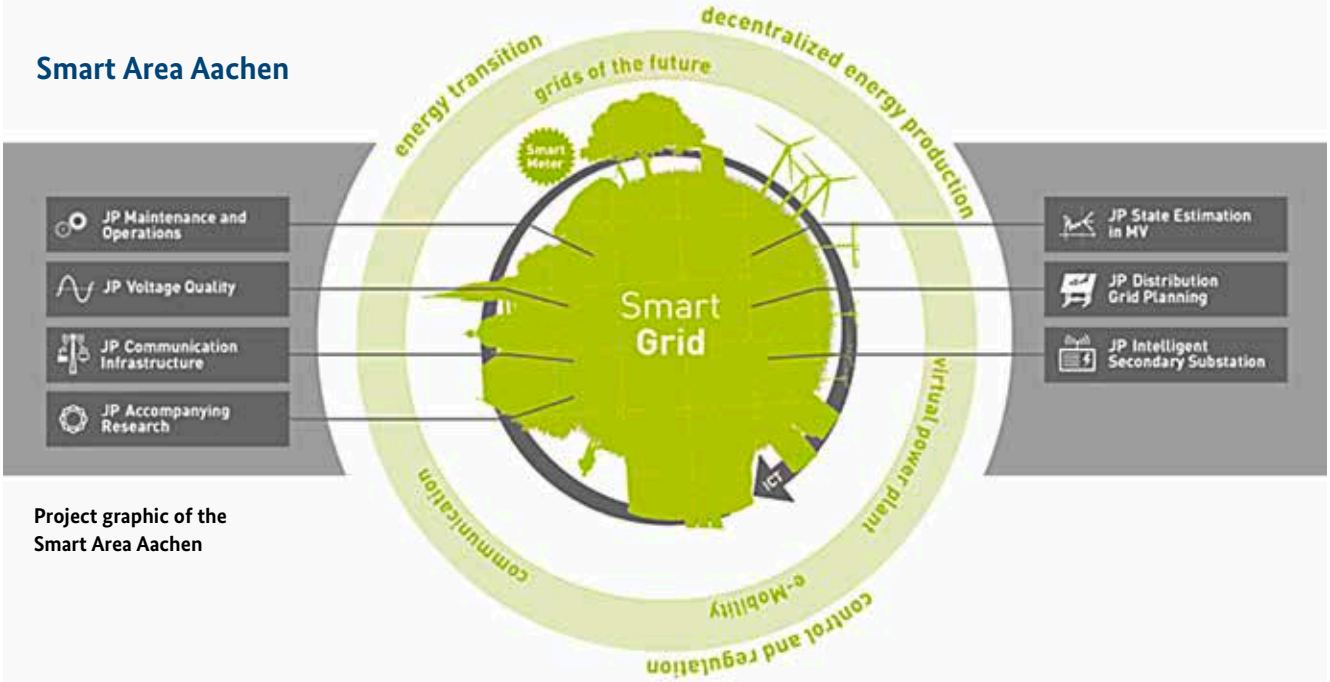
The "Verteilnetz 2020" project is part of the "Future-Oriented Electricity Grids" funding initiative. Alongside the TUM, TH Nürnberg and Infra Fürth GmbH, there are also seven manufacturers of inverters, local grid stations, battery storage systems, measurement technology, grid automation and communications technology involved in the project.

The BMWi is funding this project with around 3.1 million euros.



HIGHLIGHT

Smart Area Aachen



Project graphic of the Smart Area Aachen

Almost a quarter of the electricity in Germany is already generated by renewable energies – and this figure is set to rise further. The highly fluctuating and decentralised electricity fed into the grid poses challenges for the infrastructure. The task of grid operators and electricity suppliers is now to face these challenges with intelligent, flexible and adaptable solutions. Especially at the low and medium voltage level, these systems must be able to control and compensate for future electricity generation and consumption. This not only requires the expansion of the grid but above all the restructuring of the grid to also guarantee the seamless quality of supply in future.

These problems facing the distribution grid are the themes being investigated in the **Smart Area Aachen** research project. The project comprises a total of seven associations and 13 partners. This includes STAWAG Stadtwerke Aachen AG as the project coordinator, RWTH Aachen in the form of the institutes IAEW and IFHT, Maschinenfabrik Reinhausen GmbH, the institute ie³ at TU Dortmund, ABB AG, the Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft e. V., Nexans Deutschland GmbH, PSI AG, BET Büro für Energiewirtschaft und technische Planung GmbH, INFRAWEST GmbH, Kisters AG, SAG GmbH and the VDE Verband der Elektrotechnik ElektronikInformationstechnik. The project brings together experts from industry and research to address issues of energy technology and information and communications technology. The BMWi is providing funding of approx. 5 million euros for this major project over a period of five years.

The focus is being placed on the integration of decentrally generated renewable energy into local authority supply structures while maintaining a uniformly high security of supply. For this purpose, the scientists are developing new components together with operational, maintenance and grid planning concepts for an intelligent electricity grid and then testing them on the 3000 kilometre electricity grid operated by STAWAG in Aachen. The project started at the end of 2012 and runs until 2017. The first results from test operations were presented by the project partners at the Berliner Energietagen conference in May 2014.

The individual projects deal specifically with intelligent local grid stations, estimating the status of the grid, grid planning and testing of the voltage quality and are dedicated to issues on the themes of maintenance and communication, while also being supplemented by accompanying research into smart grids. Innovative elements such as local grid stations with intelligent fault recognition or status estimators for medium voltage grids are being integrated into the intelligent distribution grid in the Smart Area Aachen, which also encompasses new planning and maintenance methods. The first components and processes have already been successfully implemented in the Stadtwerke Aachen electricity grid and the project has thus delivered some initial deeper insights into which measures will make the distribution grid more efficient.

Multi-megawatt laboratory

The expansion of renewable energies with their fluctuating feed-in characteristics, as well as the electrification of the transport and heating sectors, requires new approaches for the integration of decentralised generators, consumers and storage systems into the grid. Power electronics are playing a central role in this area, covering a whole range of aspects from the generation of electrical energy in renewable energy power plants and the continental transport of electrical energy in high voltage direct current transmission connections through to the integration of decentralised generators and consumers into low voltage grids.

The **Multi-Megawatt Laboratory** project, funded by the BMWi and the BMBF, involves the establishment of an outstanding research site for power electronics, control technology and electrical energy technology at the Fraunhofer Institute for Solar Energy Systems ISE. In this cross-departmental project, the Fraunhofer ISE can extend its research into power electronics to include outputs of up to 10 megawatts and expand the development of power electronics to include the medium voltage range. In addition, the Fraunhofer ISE is taking the first steps towards conducting research into electrical energy technology and control technology for the high voltage range.

In the **Low-Voltage Laboratory** subproject, a globally unique power electronics laboratory is being constructed that will enable the development and practical testing of power electronics transformers for a variety of areas dealing with renewable energies and decentralised storage systems. The coupling of consumers, generation plants and storage systems will be made possible with the help of power electronics transformers, for example using innovative inverters. These active and dynamic transformers should be able to convert electrical energy in a more efficient and resource-saving way in future. The researchers are thus investigating, for example, the application of new semiconductor components, for example made out of silicon carbide (SiC) and gallium nitride (GaN), in order to increase the efficiency of the inverters.

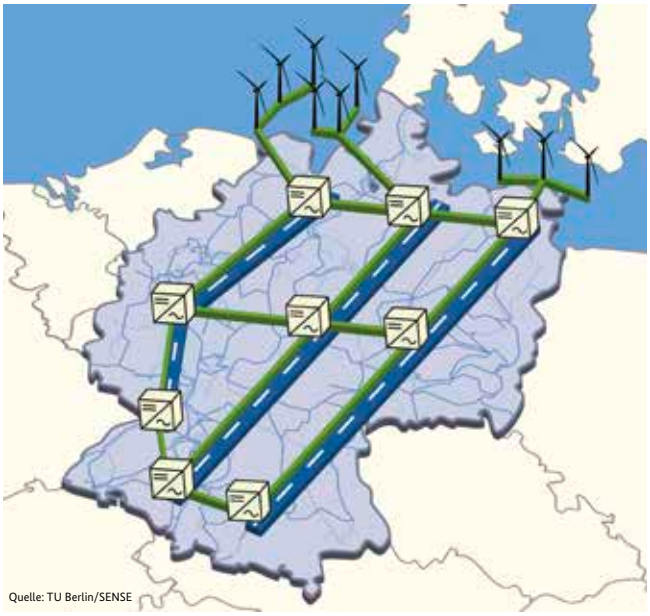
In the **Medium-Voltage and Electromobility Laboratory** subproject, a new laboratory environment will enable research and development into converters in the medium voltage range. This laboratory will be used to develop new direct current converters (DC/DC controller) for future photovoltaic power plants, which will increase the output

Medium voltage transformer with multiple connections on the low voltage side: Different test subjects with a variety of supply voltages can thus be connected to the transformer

voltage from the solar modules to a medium voltage level. The electricity from the photovoltaic modules is then collected at a DC medium voltage level and fed directly into the medium voltage grid with the help of a medium voltage converter (DC/AC). This increases the energy efficiency and reduces the costs for electricity from renewable energy power plants. Furthermore, the aim is also to better integrate electrical energy storage systems, especially in electric vehicles, into the grid.

The BMWi is funding the Low-Voltage Laboratory and Medium-Voltage and Electromobility Laboratory subprojects with a total of 6 million euros.

Project graphic for OVANET



OVANET: acceptance friendly overlay grids for the future

Current discussions about the expansion of the 380 kV alternating current transmission grid demonstrate that the realisation of new transmission systems can expect resistance from the general public. New approaches are thus required for the establishment of an overlay grid that will find more acceptance amongst the public by using innovative direct current technologies and new realisation concepts. A consortium made up of the TU Berlin (project coordinator), TU Darmstadt and TU llmenau, all of the transmission grid operators in Germany (50Hertz, Amprion, TenneT, TransnetBW), the Verband der Elektrotechnik Elektronik Informationstechnik e.V. (VDE) and the technology companies Siemens AG, Nexans Deutschland Industries GmbH & Co. KG, Südkabel GmbH and ILF Beratende Ingenieure GmbH are now focussing on this subject.

The basic idea behind **OVANET** is the use of existing corridors created by motorways for the power lines. The cables will be laid along the hard shoulders in tunnels. In the process, new technologies will sustainably reduce the installation costs for the tunnels and cables. A particular scientific challenge lies in the planning and operation of a direct current overlay grid that will stretch from the offshore wind farms in the north to the load centres in the south of the country and be connected to the alternating current grid via converters at suitable connection points. Only point-to-point connections were common in standard direct current technology, but the OVANET project will conduct research into meshed grids. Innovative solutions will be created for managing the system that include power flow regulation and frequency stability. Improved models will enable precise analyses of the stability of the system and improve its behaviour in the case of faults. At a component level, the focus is being placed on grid protection.

Competitive grid operation with renewable energies

The expansion of wind energy and photovoltaic power plants poses new challenges for the grids. In order to keep the expansion costs as low as possible, new grid structures and competitive solutions for renewable generation plants are needed.

In the project Future-Oriented Grids for the **I**ntegration of **R**enewable **En**ergy Systems, known as **IREN2**, a consortium from the areas of science and industry is investigating concepts to improve the integration of renewable energies at a distribution grid level.

On the one hand, the project partners aim to propose the use of micro grids as island systems for decoupling certain grid regions so that electricity can continue to be supplied to an area in the event of a fault at a superordinate grid level, while on the other hand, they recommend the concept of topological power plants. Topological power plants are sections of the grid in which generators and consumers can be jointly managed like in a conventional power plant. This type of grid section can contribute to the stability of the system as a topological power plant and thus take over the tasks of conventional power plants.

These grid structures are being investigated by the consortium from both an economic and technical aspect. The project partners aim to identify the cheapest expansion option for various grid structures and analyse different operating strategies. The technical analysis will also include stability tests and the development of concepts for providing security.

To enable PV power plants to supply grid and system services in the future, they should be combined with battery storage systems and fossil fuel generators and integrated into a joint management system

The project partners are testing and validating the operating strategies in Wildpoldsried in the grid area managed by Allgäuer Überlandwerk GmbH. The generation of electricity from renewable energies is today already five time higher in this area than the level that they actually require. As a result of the predecessor project IRENE (Integration of **R**enewable **En**ergy **S**ystems and Electromobility), the region already possesses an intelligent grid with corresponding measurement technology, as well as a stationary battery storage system.

The consortium includes Siemens AG, Allgäuer Überlandwerk GmbH, the University of Applied Sciences Kempten, the RWTH Aachen and ID.KOM Networks GmbH.

The BMWi is funding IREN2 as part of the funding initiative "Future-Oriented Electricity Grids" with around 3.1 million euros.

PV power plants should supply grid services

There is currently a major price war in the photovoltaic sector. At the same time, the feed-in remuneration for electricity generated from photovoltaic power plants is falling. In order to increase the attractiveness of photovoltaic (PV) energy, a consortium from the areas of science and industry is developing a new concept for PV power plants in the **Photovoltaic Power Plant of the Future** project. The aim of the project partners is to combine PV power plants with battery storage systems and fossil fuel generators and then integrate them into a joint management system. These hybrid power plants are also set to take over grid and system services.

The PV Power Plant of the Future should provide all of the necessary services for the operation of electricity grids. Grid services such as frequency regulation, secondary regulation, voltage regulation and a cold start-up capability were traditionally supplied by fossil fuel power stations. If PV power plants can take over these system services in the future, it could compensate for the lost regulating capacities from those conventional power plants that have been shut down. It would also enable grid stability to be guaranteed exclusively by renewable energies. In order to make this possible, the project partners are developing comprehensive technical solutions for PV inverters and other component parts to upgrade them to cope with these broader requirements.

In addition, the project foresees research into and the develop of innovative options for making cost savings in all areas of PV power plants in order to strengthen PV as an affordable part of the renewable energy mix – despite the falling feed-in remuneration. With a view to the total costs of PV power plants over their entire lifetime, the project partners are developing analyses for reducing faults and outages, as well as solutions for new types of service and maintenance equipment.

These research and development measures should strengthen the competitiveness of German PV suppliers both at home and abroad and thus contribute to increasing the level of expertise and securing jobs in the long term.

The consortium under the coordination of BELECTRIC GmbH includes Adensis GmbH, Brandenburg University of Technology Cottbus-Senftenberg, GE Energy Power Conversion GmbH, Fraunhofer Institute for Solar Energy Systems ISE, Jurchen Technologie GmbH, MTU Friedrichshafen GmbH and Padcon GmbH.

The BMWi is funding the PV Power Plant of the Future project as part of the funding initiative "R&D for Photovoltaics" with around 4.8 million euros.

Regenerative combined power plants/virtual power plants

Selected funded projects

Guaranteeing the reliability of virtual power plants

Electricity suppliers are increasingly supplying their customers from a portfolio of different renewable energy technologies. In order to guarantee security of supply and keep the costs of the future electricity supply at a calculable level, it is important that the supplier knows how reliable individual components are and that they are able to utilise possible synergy effects and exploit cost saving potential during operation and maintenance.

In the **Hera-VPP** project, scientists at the Fraunhofer Institute for Wind Energy and Energy System Technology IWES are investigating the reliability of and upkeep necessary for virtual power plants. The researchers are analysing the effects of technical or maintenance-related breakdowns for the overall existing system comprising decentralised energy generators, storage systems, flexible loads and a wide variety of grid components. On the basis of these results, they aim to subsequently derive future requirements for research in this field and the optimisation potential for virtual power plants.

Due to the decentralised structure, the size and the large number of individual generation units, the risk of failure will be statistically spread, meaning the risk of grid outages will be reduced. What is important to know here is the size that virtual power plants need to be for this to be the case.

As a result of their decentralised nature, higher costs result from the operation and maintenance of virtual power plants. The scientists also aim to qualitatively depict the cost savings potential in this area. The knowledge gained about the entire system can flow into the forecasts for the power output from virtual power plants and be used to optimise maintenance management systems.

The BMWi is funding this project with around 300,000 euros.

The expansion of wind energy and photovoltaic power plants poses new challenges for the grids. In order to keep the expansion costs as low as possible, new grid structures are needed

System services

Selected funded projects

Coordinating decentralised power plants – providing system services

During the course of the energy transition, renewable energy generation plants based on wind and photovoltaic power are increasingly replacing conventional power plants. However, the conventional power plants continue to guarantee grid stability and security of supply in the distribution grid by providing system services. System services such as frequency stability and voltage stability, the re-establishment of the electricity supply and a cold start-up capability can only currently be offered by transmission grid operators using decentralised power plants to a very limited extent. This is due to the fact that more than 90 percent of all decentralised power plants feed into the system at the distribution grid level, which is subordinate to the level of the transmission grid operators.

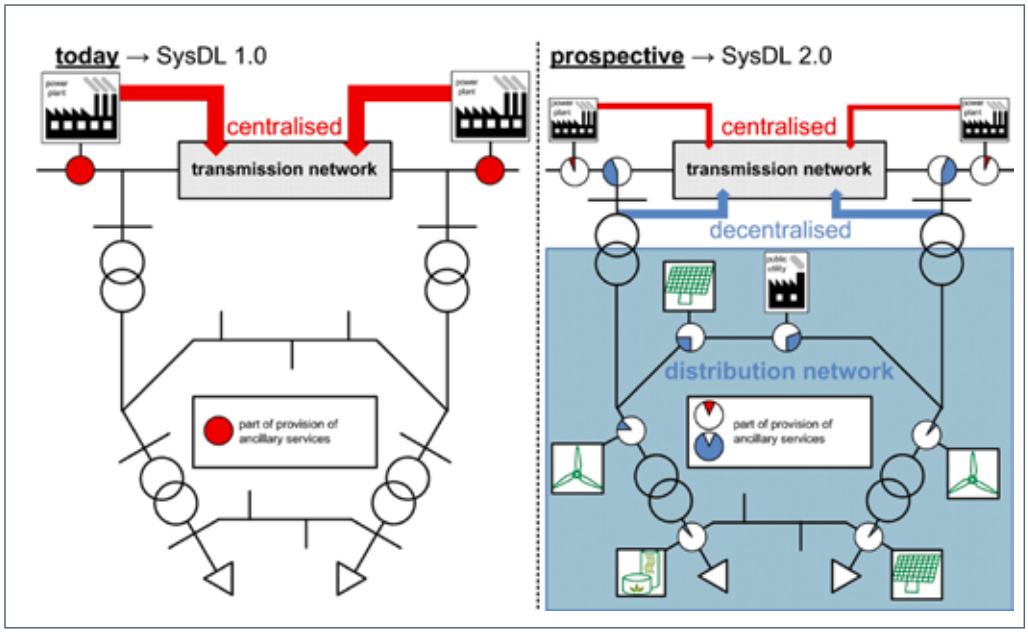
In the **SysDL 2.0** joint project, a consortium from the areas of industry and science aims to create the technical basis that will allow renewable energy generation plants that feed into the distribution grid to provide system services in the future. The decisive factor here is the coordination between the decentralised power plant, the distribution grid and the requirements of the transmission grid operator.

The project partners are developing the technological framework conditions and possible coordination algorithms for distributed power plants. In a real-time test environment, they are simulating how future control systems for system services can be coordinated and implemented from the distribution grid. On the basis of these simulations, the project partners will subsequently evaluate their system concept in the grid areas operated by enso NETZ, MITNETZ and 50Hertz.

It should also be possible to directly scale the findings and the developed technologies to other distribution and transmission grid operators. The consortium thus aims to create the technical and organisational conditions for guaranteeing an efficient, cost-optimised and secure supply for the operation of the electricity grid even when high proportions of the electricity are generated by decentralised and fluctuating sources.

Drewag NETZ GmbH is coordinating this joint project in which the following partners are involved: Mitteldeutsche Netzgesellschaft Strom mbH, 50Hertz Transmission GmbH, the Technical University of Dresden, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES, Siemens AG, F & S Prozessautomation GmbH and the University of Kassel.

The BMWi is funding SysDL 2.0 as part of the funding initiative “Future-Oriented Electricity Grids” with around 3.2 million euros.



Current and future system services

Energy efficient buildings and cities

Buildings and cities account for a large proportion of the demand for energy: Up to 40 percent of total German energy consumption is accounted for by the residential building stock, non-residential buildings in the service sector and public authority buildings such as swimming baths or schools. Heat and electricity have always been on a par in this area. The importance of buildings and districts in the implementation of the energy transition is just as indisputable as the fact that the immense potential available here is difficult to exploit due to the complex structures and different spheres of interest. This is compounded by the fact that the planned restructuring of the energy industry will mean that former end consumers will become generators of power and at the same time direct consumers who cover a high percentage of their own energy requirements. The German federal government has set itself the goal of saving 80 percent of primary energy in the building sector through the energy transition.

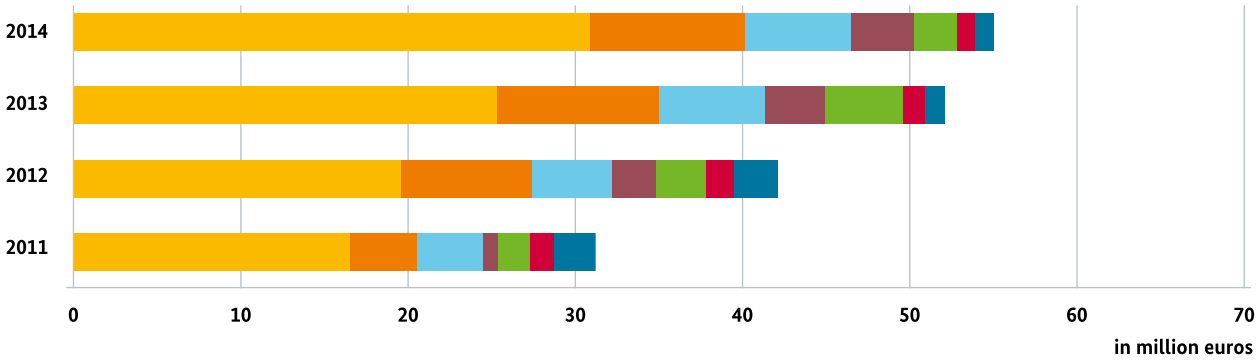
Market developments in Germany and across the world

Buildings have an average lifespan of around 100 years. The renovation cycles for the building components deviate significantly from this time scale so that the complete modernisation of old buildings into plus energy buildings only happens in very exceptional cases. Although components developed through research and development activities that have been introduced onto the market are being increasingly utilised, there are nevertheless two factors posing an obstacle to the improvement of the energy balance: Firstly, the quality assurance given by planners and manufacturers through to craftsmen and ultimately the building operators is extremely prone to errors due to the many interfaces along the value added chain. Secondly, the behaviour of the user is often different to that which is expected. In the area of energy efficiency, we refer to this as the rebound effect. This principle states that an increase in energy efficiency will often lead to reduced costs, which as a result can lead to an increase in demand from the user and thus increased consumption. This ultimately cancels out the savings effect. In this respect, the simultaneous optimisation of processes alongside technological developments is of decisive importance.

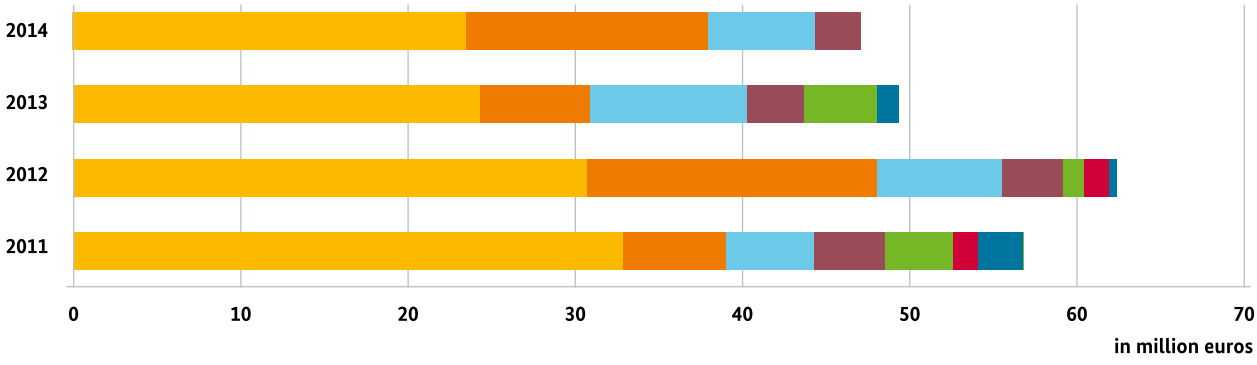
An even stronger trend towards the integrated vision of buildings and districts is expected in 2015. Tools for monitoring the energy consumption in buildings and households will also assume a more significant role on the market in future.

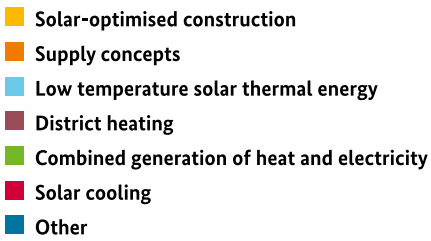
Modern heating technologies and renewable heating are a key factor in the success of the energy transition in the building sector. Uniform reductions in the energy load from existing buildings are being increasingly achieved with the aid of heating grids, storage systems and innovative district concepts for energy modernisation. The pending modernisation of the heating technology in the building stock will provide a great opportunity for the integration of solar heating. However, the current renovation rate for buildings is under one percent. The solar energy sector can expect a significant boost due to the National Action Plan for Energy Efficiency (NAPE) agreed by the German Federal Cabinet in December 2014 and the measures announced therein.

Energy efficient buildings and cities: Distribution of funding between 2011 and 2014



Energy efficient buildings and cities: Trend in the volume of newly approved funding since 2011





Solar thermal energy offers great potential both in Germany and also worldwide. A study published by the Fraunhofer Institute for Solar Energy Systems ISE forecasts that a third of decentralised heating systems and two thirds of central systems in heating grids will be equipped with solar thermal energy by 2050. However, the German market has almost halved since the boom year of 2008. For the first time, new installations covered less than one million square metres in 2014. The proportion of heating consumption accounted for by solar energy thus currently lies at just 0.5 percent. In contrast, the market for solar thermal energy is growing continuously worldwide. There are now around 385 million square metres of collector area or almost 270 gigawatts of thermal output installed (as of 2012).

Districts offer many opportunities for the optimised use of energy

Progress in research and development

A number of research projects in the areas of quality assurance, plant technology and building technology were successfully completed in 2014. Other older projects such as FensterCheck were also presented to the sector at trade fairs (Glastec 2014). The level of maturity found in newly developed individual technologies is often very high from a scientific standpoint. However, transferring these technologies into marketable products is often more complicated than in other research fields: due to the rebound effect and challenges faced in the area of quality assurance due to the high number of actors involved in the implementation process. Important contributions in this area are being made by the EnOB Symposium for Energy Innovation in Building at the Zeche Zollverein in Essen in which research and practice are being brought closer together. In addition, the role of local authorities as a driving force in the energy transition was discussed at the EnEff-Stadt congress in Berlin. The important role of research into the energy efficient provision of heating and cooling was a theme at the status seminar EnEff-Wärme in Cologne. This focussed on the implementation of innovative waste heat combined systems and innovative storage and supply technologies.

Solar thermal energy has reached a very high level of technical maturity – at least in its traditional fields of domestic hot water provision and in supporting heating in single-family houses and apartment buildings. A significant reduction in heating costs continues to be important. This will also require the further development of individual components that make up the system, such as collectors and thermal storage systems. Decisive factors for achieving cost reductions at a system level are, however, a sweeping level of standardisation, a more simple installation, functional security and a stable yield. Therefore, funding is being increasingly awarded to research into system integration, as well as to concepts ranging from solar plus energy houses both for new constructions and also the modernisation of existing building stock, through to district solutions and plus energy estates.

Other important growth markets in the future will be solar local heating and solar process heating. A breakthrough is expected when solar energy represents a solid technical and economical alternative to the use of energy sourced from fossil fuels.

By founding the research network “Energy in Buildings and Districts” on 2 October 2014, the BMWi responded to the challenges faced in increasing the utilisation efficiency and

the sustainable conversion of energy in the context of buildings and districts (see page 96). The aim of the network is to generate synergies for the successful implementation of energy policy goals by bringing together the most important players from research, politics and business and by developing systematic solutions for the future.

Strategically, the research network is based on the tradition of pooling funding concepts, as was achieved by the BMWi in the past, for example, with the foundation of "Energy-optimised construction (EnOB)". Ten years ago, research and development into new buildings and renovations, as well as their demonstration, were combined under the research brand EnOB. This led to an increase in efficiency in the implementation of funding measures and to better communication of the results. The research network, which now brings the themes of buildings, heat provision, decentralised conversion of energy and energy efficiency in a city context together, will once again significantly improve the communication and transfer of the research into practice, while also moving towards a solution for the special systematic challenges faced in this complex field of research, especially in light of the energy transition.

Strategy for research funding

On the basis of previous experience, system-related challenges will require the greatest level of research and development work in the future. On the one hand, innovations in the area of active and passive components in buildings and districts will represent a relevant field of research, while on the other hand, the focus will be placed on technologies for improved transparency in energy performance from the level of components right through to the level of districts. Another area of research comprises the methods, processes and structures that will make a transformation of the German market possible. However, this could also mean quicker product development and launch onto the market through improved processes. A further area involves electronic planning aids for a broad spectrum of applications, which will help to resolve existing interface issues and thus push forward the area of quality assurance. The field of low temperature solar thermal power also has a place in the overall strategy of the BMWi when it comes to research and development into energy efficiency in buildings, districts and cities.

The framework conditions for the attainment of the energy policy goals in the context of buildings and cities are positive. In accordance with the 6th Energy Research Programme, these goals will also form part of the planned announcement of the joint funding programme "Solar Building & Energy-Efficient City" at the beginning of 2016.

The project funding provided by the BMWi in the area of energy efficient buildings and cities for a total of 83 newly approved projects was 40.7 million euros in 2014 (2013: 40 million euros). A total of 48.8 million euros of funding was provided to ongoing projects (2013: 45.8 million euros).

In the area of low temperature solar thermal energy, funding of 6.5 million euros was provided to 15 newly approved projects (2013: 9.5 million euros). The expenditure on ongoing projects in this area stood at 6.4 million euros in 2014 (2013: 6.5 million euros).

SPECIAL TOPIC

The funding initiative EnEff:Stadt for energy-optimised districts

Energy efficient city districts can make an important contribution to the energy transition. The Federal Ministry for Economic Affairs and Energy is intensifying the long standing research activities for greater energy efficiency in the communities with the initiative "EnEff:Stadt – Research for an Energy Efficient City". By networking and integrating a number of research fields, including energy- optimised buildings and efficient supply structures, the focus is being placed above all on economically sensible energy innovations at a district level. This initiative launched in 2007 has already been able to demonstrate successes in a series of ambitious projects.

In contrast to measures taken for individual buildings, measures at a district level can be integrated into the municipal or regional energy concept, as well as into existing structures. Integrated planning at a district level can accelerate the exploitation of the great potential available because systems are more efficient and thus more economical. At the same time, it avoids the problem that solutions for individual buildings can have a negative influence on the overall system. This involves, for example, CHP plants that can make a contribution, in combination with heating grids and storage systems, to load balancing due to fluctuating wind or solar electricity.

The planning and implementation of energy efficient district concepts is neither state-of-the-art technology nor standard practice. This is where the research initiative EnEff:Stadt comes into play: Ambitious demonstration projects in typical city districts will deliver practical experience during the application of innovative technologies and planning aids, implementation management and process optimisation. The results and conclusions will be scientifically evaluated and can be transferred to other projects and locations.

A team of scientists is accompanying the research work and pilot projects. They offer advice on setting priorities, develop evaluation criteria and supplementary measurement programmes and carry out the scientific evaluation, cross-section analyses and dissemination of results. In addition, the researchers accompanying the projects investigate the use of planning tools and develop recommendations for what action should be taken in the districts. The specialist and administrative management of the research is provided by Project Management Jülich (PtJ) on behalf of BMWi.

Aerial photograph of Berlin Adlershof

One of the projects within the research initiative is the "Energy Strategy Berlin-Adlershof 2020". The Berlin Adlershof Technology Park is one of the largest high-tech, scientific, business and media locations in Europe. A total of 23,000 people live and work there. This district has a high level of energy consumption as a result. In order to increase energy efficiency, an innovative energy concept was developed in the "High Tech – Low Ex: Energy Efficiency Berlin Adlershof" project up to 2013. It envisages a 30 percent reduction in primary energy consumption in the period from 2020 to 2030 in comparison to the extrapolated trend.

The project "Energy Strategy Berlin Adlershof 2020" is based on this concept and has been successively implementing the energy efficiency measures in practice

in buildings, processes and for the energy supply since the autumn of 2013. There has also been an intensive exchange of information with other model districts in Germany, Austria and Switzerland. The involvement of stakeholders – which is fundamental to the success of the efficiency measures – is ensured by the Site Energy Manager. This is achieved in close cooperation with partners from the areas of research and science and with the support of the Berlin Senate Department for Urban Development and the Environment. The BMWi is funding this project with around five million euros. WISTA-Management GmbH, Siemens AG, the HTW University of Applied Sciences Berlin and the Technische Universität Berlin are participating in the project.

Berlin Adlershof hosted the second EnEff:Stadt congress organised by the BMWi in January 2014. It targeted scientists, city planners, architects, decision makers from local authorities and the supply industry, as well as representatives from the energy and climate protection sectors. The congress, which attracted 200 participants, provided information on current projects and cross-section analyses, as well as discussing other central issues of the funding initiative.

In October 2014, the BMWi founded the research network “Energy in Buildings and Districts”. It aims to push forward networking and interaction between different levels of research and technology and the players involved, as well as to underline the systematic approach of energy research at the BMWi.

SPECIAL TOPIC

Solar decathlon for energy efficient houses

The Solar Decathlon is an international energy and architecture competition for universities. The best 20 entries are selected in advance during an international application process. These entries are then built and enter once again into competition with one another. This successful series of events started in the USA in 2002 as an initiative by the US Department of Energy (DOE) and has been held since then every two years.

In the alternating years between the original American competition, there has also been a European counterpart held every two years since 2010. Spain was the host for the first two European competitions. The venue in 2014 was Versailles and attracted around 80,000 visitors. The German participants came from the Frankfurt University of Applied Sciences (Team OnTop), the TU Berlin and the University of Arts Berlin (Team Rooftop) and the Erfurt University of Applied Sciences. The BMWi supported the three university teams with a total of around 960,000 euros of funding. There is also a Solar Decathlon in Asia. It took place for the first time in 2013 in Datong in the Chinese province of Shanxi, 300 kilometres to the west of Beijing.

Just like the Olympic competition of the same name, the student teams are competing with each other in a solar decathlon (Greek δέκα/déka (ten) and ἆθλον/áthlon (feat)). The participants have the task of designing an energy-optimised building, constructing it and operating it during the competition so that its own power demands are completely met by self-produced solar energy. In general, so-called "plus energy houses" are created that actually generate more energy than they consume. The houses should also be affordable. In addition, they should be comfortable, healthy and create an environment worth living in. Even the question of how the buildings will be subsequently used is also one of the ten criteria.

The teams receive up to 100 points per criterion for their entries and can thus achieve up to 1,000 points in total. In the process, they have to convince the judges on three different levels. Firstly, they need to demonstrate that traditional household tasks can be completed without any problems in the buildings, e.g. washing laundry. Secondly, the operation efficiency of the house is examined. For example, the indoor temperature in the house should be maintained in the comfort zone of between 21.7 and 24.4 degrees Celsius. And thirdly, the jury – consisting of experts from the area of architecture, engineering and communication – judge the non-measurable criteria such as the architecture, sustainability or urban planning and public relations work, as well as the creative inspiration behind the building.

The next North American Solar Decathlon will be held from 8 to 18 October 2015 in Irvine in the State of California, USA. The location for the next competition on European soil has not yet been announced. The BMWi supports efforts to further develop the competition in a European direction as part of the SET-Plan based on the Berlin Model. In the "Declaration of Versailles", the participants in 2014 expressed a wish for the European Commission to take over stewardship of the competition.

The 20 best entries submitted to the international energy and architecture competition are built and then compete against one another again

Selected funded projects

Energy efficiency and hygiene in drinking water installations

Safe and clean drinking water is a valuable commodity. The United Nations even recognises access to it as a basic human right. Yet it cannot be taken for granted that water in private and commercial buildings is safe from contamination by pathogens. The **EE+HYG@TWI** research project including the TU Dresden, the IWW Water Centre, the Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. and the University of Bonn has dedicated itself to this problem since April 2014. The project brings together multidisciplinary scientists from the areas of energy and plant technology with experts in drinking water hygiene.

The aim of this joint project is a holistic and systematic analysis of drinking water installations for future LowEx heating supply concepts for residential and non-residential buildings. While taking into account thermo-hydraulic aspects, scientists want to also identify and investigate any energy saving potential and integration options for renewable energy sources. In parallel, the effects on drinking water hygiene will be constantly quantified with respect to Legionella and Pseudomonas aeruginosa. In the process, the researchers want to find out which thermal and hydraulic conditions are necessary to guarantee a safe level of hygiene and quality by only heating the drinking water to 55 degrees Celsius. Current regulations require a temperature of at least 60 degrees Celsius for drinking water hygiene. The effects on the hygiene of cold drinking water should not be underestimated here.

The BMWi is funding this project with around 2.1 million euros. The project has an overall budget of 2.6 million euros.

Test facility at the TU Dresden, Research Group of Building Energy Systems and Heat Supply

Energy Efficiency Center (EEC)

The **Energy Efficiency Center (EEC)** run by the ZAE Bayern is an innovative research and demonstration centre for a diverse range of energy efficiency technologies that was constructed in just 2.5 years on land reclaimed from a former US barracks in Würzburg. The special feature: It was not simply the redesign and enlargement of the existing building space but within and at the building envelope new solutions for building climatisation have been tested from an economic standpoint. Innovative and energy efficient materials and systems were utilised for the construction.

The ZAE Bayern has exploited the symbiosis of innovative building elements and intelligent control technology to achieve a high primary energy yield. As a result of fine tuning efficient solutions for building envelope and supporting structures, as well as the use of modern information and communications technology, it was possible to achieve positive effects in the areas of energy savings, sustainability and comfort. This is demonstrated by the textile roof. New membranes with special roof elements allow daylight directing into the building and at the same time create a controllable intermediate climatic zone.

The ZAE Bayern aims to use the new building to demonstrate new technologies in practice and to conduct further research in their application into and carry out appropriate adaptations. The EEC building utilises, for example, solutions such as aerogels, vacuum isolation, special window frames, phase change materials, new low-e textiles, radiation cooling, different lighting concepts and sorption cooling systems. In a monitoring project, the ZAE Bayern has been investigating and optimising the installed systems and user behaviour since early 2014 in order to further reduce energy consumption.

SPECIAL TOPIC

Research network for energy in buildings and districts

Urban systems have a special role in the energy transition because they unlock the efficiency potential for the successful and comprehensive integration of renewable energies. This is true when innovative technologies and concepts are developed and quickly introduced onto the market. In order to efficiently realise this process, to increase the transparency in research funding and to transfer the results more quickly into practice, the strategic networking of all players is required. The Federal Ministry for Economic Affairs and Energy (BMWi) acted on this impetus and founded the research network "Energy in Buildings and Districts" on 2 October 2014 together with around 100 experts from the areas of business and science. Through this network, the BMWi aims to sustainably boost the innovative strength in Germany in the area of buildings and districts.

FORSCHUNGSNETZWERK ENERGIE IN GEBÄUDEN UND QUARTIEREN

The network is designed to act as an important interface between politics, research and business and create synergies in the development and implementation of new solutions in the areas of urban systems, energy efficiency, solar building construction and heating supply. An important milestone was the development of a cross-departmental funding initiative "Solar Building & Energy-Efficient City". This is due to be published at the beginning of 2016. This open invitation to players in the sector to actively contribute and to deliver impetus and recommendations for efficient funding strategies to politicians underlines the need for practical and future-oriented guidelines and their future development through dialogue.

The research network combines different funding areas for energy research at the BMWi. This includes the research initiatives "Energy-optimised construction" (EnOB), Energy Efficient City (EnEff:Stadt), Energy Efficient Heating Supply (EnEff:Wärme) and low temperature solar thermal energy.

The network brings together different interests, areas of potential and objectives with a focus on districts, buildings and energy efficiency. The results of the energy research should thus be transferred to the participators in the energy transition directly. As a result, long-term planning should also be possible through innovative technological concepts. The Ministry thus plans to combine strategic planning processes with research, development and innovation within the framework of the German federal government's Energy Research Programme and strengthen the role of energy research as a strategic instrument for the implementation of the energy transition.

The network is structurally divided into different thematic working groups. The coordination of the groups and of the network itself is organised by a team of administrators. This team is led by Project Management Jülich on behalf of the Ministry.

Project Management Jülich will be supported in the pooling and evaluation of the results achieved by the groups through accompanying scientific research. Regular yearly meetings of the network will be used to exchange experiences. The Annual Meeting of the network took place on 25 and 26 March 2015.

The Energy Efficiency Center in Würzburg

The publicly accessible heart of the Energy Efficiency Center is an integrated information centre, where there is a permanent exhibition in the lobby called “Energie Bauen” (Building Energy) that provides a comprehensive overview of the themes of energy, sustainability and building technology, offering the visitor a holistic experience.

The ZAE Bayern received the Bavarian Energy Award for the Energy Efficiency Center in October 2014.

Quality assurance for compression heat pump plants

In parallel to the increasing prices for conventional fuels, the popularity of electrically driven heat pumps is also growing. They can be an inexpensive and environmentally friendly low CO_2 application when they achieve an appropriate level of efficiency. Heat pumps draw thermal energy from the environment and use it to heat rooms or for domestic water heating.

The scientists involved in the **QSWP** joint project have dedicated themselves to the area of quality assurance for compression heat pump plants in order to increase their efficiency during operation. The partners are striving to reach this goal in two ways. On the one hand, they are conducting a large-scale field test of compression heat pump plants. This involves ground-water, air-water and water-water systems from seven different heat pump manufacturers (Alpha-Innotec, Bosch Thermotechnik, Hautec, Nibe, Stiebel Eltron, Vaillant and Viessmann). The key question was to ascertain how energy efficient heat pumps really are during real long-term operation. The results of the analysis of the comprehensive operational data were utilised in the second stage for the quality assurance of the tested pumps. On the basis of the detailed data evaluations, it was possible to formulate practical proposals for manufacturers, planners, installers and operators of these types of installations. These are supplemented by the GeoT*SOL simulations and design software that is also based on the test results. Therefore, the project has made a valuable contribution to quality assurance for heat pumps.

The Fraunhofer Institute for Solar Energy Systems ISE and the IT company Valentin Software GmbH participated in the project. The BMWi funded this project as part of the funding programme “Energy-optimised construction (EnOB)” with around 870,000 million euros.

Ultra-high performance concrete elements with integrated fluid channels for façades and building shells

The integration of solar thermal energy into façades or building envelopes can make an important contribution to the energy transition. For this reason, scientists involved in the **TABSOLAR** research project developed a manufacturing process for multifunctional low temperature façade elements such as walls, ceilings and floors for new and existing buildings. The focus was placed on solar absorbers and other thermally active components made out of ultra-high performance concrete (UHPC). This enabled delicate and yet high-tensile components that make efficient use of materials to be developed.

The focus lay on the development of thermally active building components with fluid channels. A 3D channel structure was integrated into the UHPC components. The efficient flow of liquid through the channels was guaranteed by the FracTherm® structure patented by the Fraunhofer Institute for Solar Energy Systems ISE.

HIGHLIGHT

The “School 2030 – Learning with Energy” design competition

The BMWi awards the “Architecture with Energy” prize as part of its energy research. In 2014, the Ministry awarded the prize for ideas submitted under the motto of “School 2030 – Learning with Energy” and thus honoured exemplary new constructions and renovation projects. The BMWi thus emphasised the great relevance schools have as disseminators of social innovations. The Ministry funds future-oriented building concepts as part of the EnOB research area “Energy Efficient Schools”.

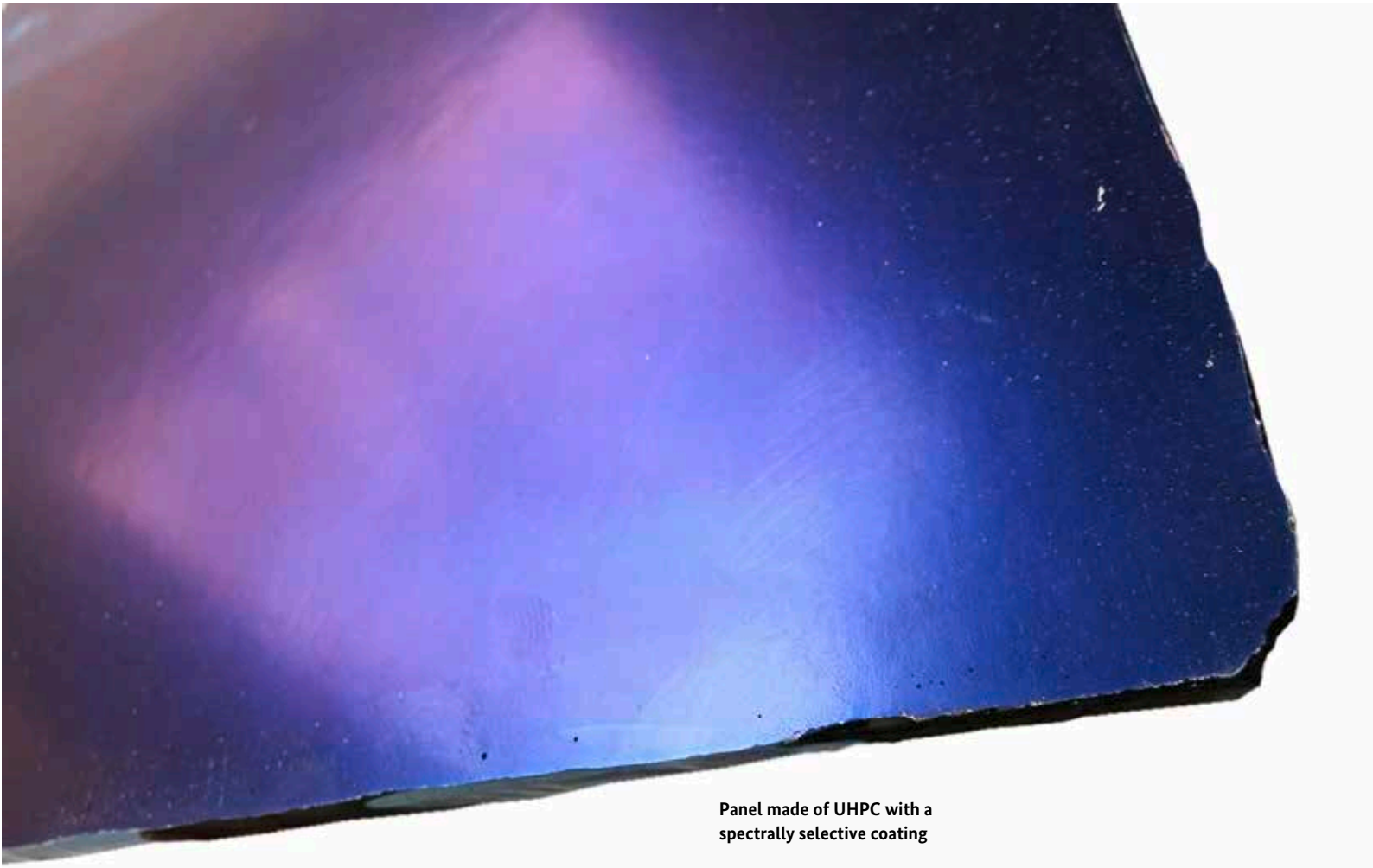
All of the concepts set new benchmarks for schools as living spaces and their energy consumption. The competition was aimed at architects, specialist planners, school authorities and consortia. The winner received prize money totalling 100,000 euros and a certificate signed by the Federal Minister for Economic Affairs and Energy, Sigmar Gabriel. The award ceremony was held on 20 May 2014 as part of the Berliner Energietage conference. The eminent members of the jury included Prof. Peter Hübner from Hübner Forster Hübner Remes Freie Architekten, Prof. Andreas Wagner from the Karlsruhe Institute of Technology (KIT), Hans Erhorn from the Fraunhofer Institute for Building Physics IBP, Roman Alexander Jakobiak from daylighting.de and architect Doris Laase from Project Management Jülich.

The specialist jury selected seven winners in the categories “overall renovation concept”, “overall new construction concept” and the special categories of “innovative thermal insulation concepts”, “innovative energy supplies”, “innovative ventilation concepts”, “innovative lighting concepts” and “innovative participatory planning”. One piece of work received an honourable mention. In the area of renovation, the estimated primary energy requirements for all of the award-winning projects in accordance with the Energy Saving Act (EnEV) was on average 65 kWh/m²a and thus lower than even the level of new construction projects.

The winner in the category “overall renovation concept” was the Zweckverband Lohr for the renovation of a school and sports centre according to plus energy standards, while improving the learning environment. In addition, Zweckverband Lohr also received a special prize for their innovative new ventilation concept. The school aims to largely produce the electricity and heat it requires itself on the property. The planners utilised decentralised ventilation devices with a high level of waste heat recovery for the outer classrooms. These allow the air volume to be individually managed based on room usage and the number of pupils.

The City of Ostfildern received a prize for its concept for a new construction of a carbon neutral primary school and a special prize for their innovative energy supply. The special feature is the planned energy network formed together with neighbouring buildings such as the town hall, community centre and sports hall. These buildings will be connected to the electricity and heating supply for the school. The lighting concept also envisages the greatest possible use of daylight, which is why blinds with flat aluminium slats for daylight redirection will be used.

The prize winners of the school design competition



Panel made of UHPC with a spectrally selective coating

Two new methods were applied during manufacturing. Firstly, the WOVENIT process was used to produce a three-dimensional weaved, warped and knitted material. The textiles produced using this method are cast with the concrete. A novel vacuum deep drawing process is then used to create two moulded parts, which are subsequently joined together. It was the fine tuning of the UHPC recipe that was ultimately decisive for the success of the concept. The system design and simulation formed another key aspect of the project.

The end result was a basis technology for the production of solar absorbers for surface heating or cooling elements. It features both structural (e.g. for load-bearing walls), thermally active (fluid conducting) and thermally passive (thermal insulation) functionalities.

The BMWi provided this project that was coordinated by the Fraunhofer Institute for Solar Energy Systems ISE with funding of 1.3 million euros. Other partners were G.tecz Engineering UG, Betonfertigteile Spürgin GmbH & Co. KG, Visiotex GmbH, Zehnder GmbH and the Karlsruhe Institute of Technology (KIT).

EnOB: The FensterCheck project: Measurement device for determining the thermal quality of glazing

Mobile measurement device assesses the Ug value of windowss

The following has been true up to now: You have to rely on the values stated by the manufacturers for the heat transition coefficient of window glazing (Ug value). It is hardly possible to carry out a precise measurement of the Ug value at a reasonable expense. If the value is to be calculated for an existing window, the complete window must be removed. The EnOB project **FensterCheck** is, however, setting new benchmarks in this area. The research consortium comprising ZAE Bayern, Kurz + Fischer GmbH, ROTO FRANK Bauelemente GmbH, tremco illbruck GmbH & Co. KG, Walter Stickling GmbH, Energy Glas GmbH and VEKA AG has developed a measurement device for precisely determining the Ug value of glazing in an installed and isothermal state.

The starting point was the development and deployment of a process that can be used during renovations to assess the energy performance of windows in existing buildings and to determine the energy saving potential of the glazing. In particular, the focus was also placed on ageing behaviour. It is now possible to measure the Ug value reliably within a few minutes using the mobile Uglass measurement device. And using the Uwin software, which was also developed during the project, it is possible to evaluate the energy efficiency of the window or even the entire façade. To do this, the user enters further parameters alongside the determined Ug value such as the proportions of the frame, the installation location (shade, shutters, etc.) and materials, as well as the solar heat gains and losses. The calculated results (given in QE in kWh/m²a) can assist the user in estimating the energy saving potential of renovating the window and make concrete comparisons between the existing window and alternatives. Furthermore, the scientists also focussed on in-line quality assurance in the manufacturing process. This involved the use of oxygen sensors in the cavity between the panes.

The target group for Uglass includes energy consultants, auditors, window and façade manufacturers, façade consultants and architects. The BMWi funded this project with around 1.5 million euros. The measurement device is available from 2015 via the website of NETZSCH-Gerätebau GmbH. ■

Low-temperature solar thermal energy

HIGHLIGHT

Solar collectors: Faster ageing for higher quality

It is strategically important to project developers and investors that solar collectors can also withstand extreme climatic influences in the long term. The quality of the products is of great importance, especially if German industry is to open up new markets. In order to support these developments, scientists at the Fraunhofer Institute for Solar Energy Systems ISE are developing tests for solar collectors and components under extreme climatic conditions.

Solar collectors are the most heavily stressed components in solar thermal power plants. They are exposed to very high temperatures and, depending on the site, also face extreme climatic conditions. For example, sites near to the coast with lots of sun offer great potential for the use of thermal solar energy but are, at the same time, vulnerable to particularly high UV exposure, humidity and salt-laden air. The result: The solar collectors degrade and age more quickly. Therefore, the Fraunhofer ISE is working together with the Institute of Thermodynamics and Thermal Engineering (ITW) at the University of Stuttgart and renowned manufacturers of collectors and components in the SpeedColl project to develop accelerated ageing tests for solar collectors and their components.

The researchers determine real exposure data for humidity, UV exposure, temperature and salt concentrations. The range of tests includes alpine, moderate and maritime sites through to measurements in arid and tropical sites. The test stands are installed on the Zugspitze, in Freiburg and Stuttgart, on Gran Canaria, in the Negev desert (Israel) and in India. In addition, the solar collectors and components are exposed to accelerated weathering tests in the laboratory. On the basis of the data recorded, the researchers develop validated ageing test processes that enable statements to be made about thermal performance during the lifespan of the collectors. The results also serve as the basis for work on standardisation.

The tests on Gran Canaria after one year of natural weathering proved especially fruitful. The scientists at the Fraunhofer ISE identified extreme corrosion due to the climate, yet the quality of the tested solar collectors remained almost unchanged. Test procedures can be developed on the basis of the measured meteorological data and data relating to the materials in order to test solar collectors at an early stage for their suitability in sunny regions with extreme climates. The researchers are developing special salt spraying tests and adapted UV tests, which means the test objects can be subjected to the stresses determined from the data quasi in time-lapse which thus simulates accelerated degradation.

The BMWi is funding the SpeedColl project with around 2.7 million euros.

In the Negev desert, scientists from the Fraunhofer ISE are investigating the ageing of solar collectors and components under extreme climatic conditions

Energy efficiency in industry

Reducing energy costs and environmental damage, strengthening the competitiveness of German industry and securing growth and employment – these are the constantly recurring challenges for the German economy. Therefore, the 6th Energy Research Programme specifies increasing energy efficiency in industry as a main focus of research. It is advocating both the constant further development of existing technologies and also the creation of new technologies that are not yet established on the market.

Market developments in Germany and across the world

Energy efficiency will become even more important as a measure of the international competitiveness and innovative strength of industry. Improvements in this area are thus key economic and energy policy issues for companies.

Although the industry, commerce, trade and services sector (IGHD) is one of the largest consumers of energy, its position in the overall energy balance has nevertheless improved significantly in the last few years. The proportion of final energy consumption accounted for by this sector has fallen from 50 percent (1990) to 44 percent (2013). This declining trend has a number of different causes. Alongside the restructuring of industry in the new German states, it is primarily due to targeted research work in the area of energy efficiency and its implementation into ongoing production processes and methods. The diverse range of technological improvements were implemented equally across the whole breadth of all sectors with a large demand for energy and were only made possible by continuous research and development activities.

Strengthening the engagement of funding for energy efficiency projects in IGHD (EnEff IGHD) significantly broadens the basis and availability of energy efficiency processes, components and products and helps to further spread the effects on electricity consumption and CO_2 emissions through the major lever of global industrial production.

Progress in research and development

The funding of EnEff IGHD research enabled a broad range of themes to be addressed. As a result, the goals of the 6th Energy Research Programme could be defined in concrete terms: the general improvement of energy efficiency, strengthening the international competitiveness of German companies and the pace of innovation in the area of energy efficiency, improving the environmental compatibility of products, services, etc., reducing corporate risks in research projects, supporting the expansion of internal capacities for research within companies, measures for reducing costs for the German energy supply system and supporting economic growth and employment in Germany.

It is only possible to provide a few examples of the wide range of different projects provided with funding. The commissioning of the high temperature superconductor cables as part of the AmpaCity project in 2014 was a first fundamental step in the technical realisation of loss-free electricity transmission using HTS technology. As part of the ENPRO consortium, it was possible for the first time in a major research project to bring together most of the major players – such as Bayer, BASF, EVONIK – to work on the theme of energy efficiency and process acceleration in the chemical industry. In the "ETA-Factory: energy-efficient manufacturing of the future" project, a significant milestone was achieved with the laying of the foundation stone for the company building in 2014. Focussing on the energy efficient handling of raw materials and intermediate industrial products, the RETURN project was able to make progress in the cleaning of titanium chips for their future recycling. In the Pegasus I/II and Poseidon projects, progressive gains in energy efficiency in drive systems through the application of coating materials and lubricants have been and will be achieved.

In the study of the thermoelectric effect, the HighTEG and ThermoHEUSLER projects have not only produced quantities of thermoelectric materials relevant for industry but have also developed and investigated different fields of application for thermoelectric systems for the utilisation of industrial heat from vehicles, heating units or industrial plants. The results that were collected through the amalgamation of information from both joint projects will enable even greater technological leaps to be made in the future. On the basis of the positive results achieved up to now with flameless oxidation processes – so-called FLOX processes – with very high levels of thermal efficiency, it should be possible to expand this technology from the medium performance range to also include small micro-FLOX and large mega-FLOX burner systems with almost no nitrogen oxide emissions.

These project results and goals provide examples of the diverse range of possible applications, as well as the advances that were made and followed up on in the area of energy efficiency in industry in 2014. They were supplemented by associated projects such as the development of a zeolite heat pump as a gas adsorption heating pump or the "Ecoloop" project that focuses on the recycle-to-gas process.

The individual initiatives were flanked by the "Research for energy efficiency in industry and GHD" series of workshops, which were organised by the project applicants, specialists and representatives from the BMWi in 2014 on the themes of thermoelectrics, ENPRO, heat pumps, high pressure technology and tribology. Internationally, the involvement in the IEA was recognised in the executive committees of the IEA-HP, IEA-IETS and IEA-ECES areas.

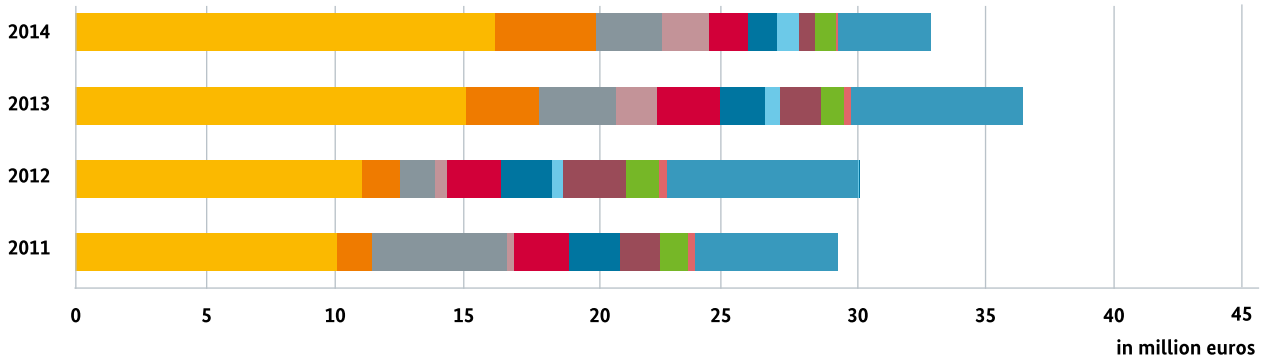
A total of 32.9 million euros of funding was provided by the BMWi in 2014 (2013: 36.4 million euros) for a total of 274 projects. There were 83 newly approved projects with total funding of 38.6 million euros (2013: 33.8 million).

Strategy for research funding

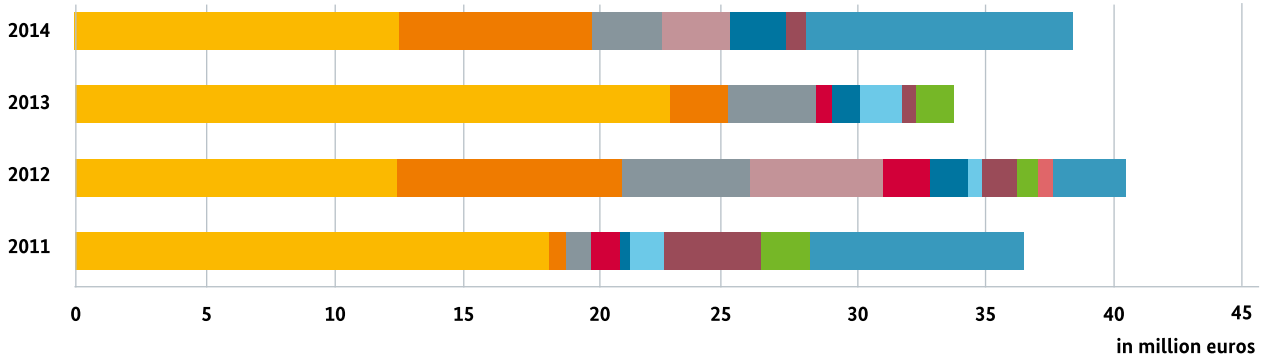
This research area covers a broad thematic and technological spectrum, which at the same time is centred on key issues. The research measures based on the 6th Energy Research Programme will also focus in future on mechanical engineering, vehicle construction, electrical engineering, precision engineering/optics/EBM goods, heat pumps, coolants and cooling technology, industrial furnaces and process heat, the iron and steel industry and the chemical industry.

Other important themes for the future funding policy must be considered in coordination with basic research, such as innovative developments in thermal process technology (particularly in the non-ferrous metal, ceramics, cement and glass industries), energy efficient process technology in the chemical industry (incl. the processing of plastics and rubber), the optimisation of reactor technology and process

Energy efficiency in industry: Distribution of funding between 2011 and 2014



Energy efficiency in industry: Trend in the volume of newly approved funding since 2011



- Mechanical engineering, vehicle construction, precision engineering, optics, EBM goods
- Chemical industry, production of plastic and rubber goods
- Heat pumps, coolants
- Mechanical and thermal separation processes
- Extraction and processing of rocks and earths, fineware, glass industry
- Heat exchanger
- Non-ferrous metal industry
- Iron and steel industry
- Industrial ovens
- Solar process heat
- Other

chemicals, shortening of the process chain, energy efficient manufacturing technology, improved process technology in the food and beverages, textile and paper industries, as well as innovative handling technologies for residual materials, waste, water or emissions.

In terms of improvements in efficiency related to electrical energy, relevant themes include highly efficient electric motors, electric installation and industrial robot technology, optimisations for heat and cold generation with electricity, efficient electrical household devices, short-term electrical storage systems for special industrial applications, new plant, generator and thermal electric concepts for efficient, decentralised electricity generation with smaller output (up to approx. 10 MW), and new technologies and applications for high-temperature superconductor cables.

The focus now and in the future will also be placed on cross-sector themes such as new technologies for the use of waste heat, new approaches for the use of replacement fuels (such as process gas), innovations in measurement, management and control technology for optimising processes, new methods for fragmentation, agglomeration, separation, classification and sorting, cooling and heat generation with compression, adsorption and absorption, energy and demand-side management systems, drive technology and mechanical power transmission, energy efficiency through material efficiency, the increased coupling of numerical simulation and modelling and its practical application.

In the long term, the trends and themes in the area of EnEff IGHD point toward greater use of membrane technologies in industrial separation processes, miniaturised analysis technologies that can be integrated into processes, more intensive recycling of energy and substances from residual materials, logistics and high-pressure technologies, as well as the improved industrial production of thermoelectric materials.

The funding of projects should continue to encourage companies to further develop actual and scientifically or technically feasible efficiency potential on their own or in a consortium with suitable partners (SME, large companies, research institutes and universities).

Recycle-to-Gas plant from the project ecoloop® (see page 107)

Selected funded projects

Expanding the limits of application for FLOX technology

Flameless oxidation processes, so-called **FLOX** processes, are considered a particularly environmentally friendly burner technology for industry. The fuel is burnt in the FLOX process without the formation of a flame in a reaction chamber. This avoids the development of hot spots that occur in traditional combustion with a flame, which cause the formation of NO_X. In order for flameless oxidation to occur, it is necessary to maintain defined conditions for the fuel and the recirculated exhaust gas. This process stands out due to its very high level of thermal efficiency with almost no nitrogen oxide emissions (NO_X emissions). Yet there is still a lot of further potential for development in this area of research.

A consortium of WS – Wärmeprozesstechnik GmbH and the RWTH Aachen – which has received funding of 500,000 euros from the BMWi – is now carrying out research into greater scalability of this process. The scientists want to expand the previously established medium performance limits for this technology of approximately 20 to 300 kW and open it up for a range from 2 kW (micro-FLOX) to 2 MW (mega-FLOX). The changes to the volume/surface area ratio could trigger previously unknown effects. This means that in-depth tests on burner test stands are required.

Areas of application for the small performance range include, for example, small test facilities or residual gas incineration plants, while the larger performance range would be suitable for applications in chemical engineering and for large heating furnaces, such as walking beam fur-

SPECIAL TOPIC

High-temperature superconductor cables for loss-free electricity transmission

Every metre travelled by electricity in traditional copper cables results in a loss of energy due to electrical resistance. Superconductors offer an alternative solution because they have a greater current density than copper and thus make it possible to have more compact cables. In addition, the reduced loss in power when using superconductors means a high voltage is no longer necessary. As a result, substations that convert between high and medium voltage are also no longer required. This offers advantages particularly in inner city areas.

Superconductors use conductive materials whose electrical resistance drops to zero as soon as their temperature falls below a certain value known as the transition temperature (T_C). The T_C is specific to the corresponding change in the material from being a normal conductor to being in a superconducting state. Liquid nitrogen (N_2) is used in order to cool the conductors to their operating temperature. The higher the transition temperature, the lower the amount of cooling required.

High-temperature superconductors (HTS) are made of ceramic materials with transition temperatures (HT_C) of around minus 180 degrees Celsius, which is significantly higher than traditional types of superconductors that have transition temperatures of just minus 263.15 degrees Celsius. The HTS are thus more energy efficient and resource efficient. The challenge lies in producing flexible superconducting cables on an industrial scale out of brittle, ceramic source materials in a cost effective manner. As part of the 6th Energy Research Programme, the BMWi is supporting a number of projects in this area that are focussing on the further development of HTS cables and tapes, as well as on HTS generators and induction furnaces.

One important research project is AmpaCity, a consortium consisting of RWE Deutschland AG, Nexans Deutschland GmbH, Nexans SuperConductors GmbH and the Karlsruhe Institute of Technology (KIT). As part of this project, which has received 5.9 million euros in funding from the BMWi, the project partners have laid the longest superconducting cable in the world to date with a length of 1,000 metres in the city centre of Essen. This cable transfers on average five times as much electricity as traditional solutions. The test operation has been running successfully since April 2014 and provides power to around 10,000 households. It is possible in future that compact high-performance cables, such as those used at AmpaCity, will gradually make high-voltage lines and substations unnecessary in densely populated urban areas.

Alongside HTS current limiters, second generation HTS tape will be one of the most important forms of high-temperature superconductors in the future. This is due to the diverse range of applications for these types of wires in industry and energy technology. In order to make these currently expensive solutions more economical, the SupraTech project is working on the development of a process for the industrial, largely automated production of superconducting tapes for applications in energy technology. DEUTSCHE NANOSCHICHT GmbH and THEVA Dünnschichttechnik GmbH are also participating in the project. The BMWi is funding this project with around 8.6 million euros.

Continuous production of superconductor bands at Deutsche Nanoschicht GmbH

naces and pusher-type furnaces. FLOX technology provides the opportunity for designing processes that are more energy efficient and environmentally friendly. The scientists are also investigating the influence of fuel composition, meaning the ratio of combustible gas, oxygen and ambient air, as well as the effect of preheating the air.

Zeolite heat pumps

There is a particularly high potential for energy efficiency in the areas of heating and cooling in Germany. This is true both in a private and also a commercial context. The use of heating pumps has the positive effect of reducing primary energy consumption.

In the **ADOSO** joint project, the Fraunhofer Institute for Solar Energy Systems ISE, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, SorTech AG and Stiebel Eltron GmbH are developing a gas adsorption heating pump for higher application temperatures (55/45 degrees Celsius) that uses a crystallised zeolite heat carrier. In addition, they aim to develop a new type of evaporator-condenser apparatus. The crystallisation occurs here on a three-dimensional heat transfer structure made of fibres. The aim is the ongoing optimisation of this structure during the course of the project to improve the transfer of material and heat and increase its lifespan.

The challenge facing the scientists is to ensure that the complete aluminium surface of the fibre structure develops a zeolite coating during the crystallisation process. In order to do this, the project partners are particularly concentrating on the further optimisation of the zeolite through chemical changes.

In contrast to standard lamella heat exchangers, this approach enables the surface area to be increased by a factor of 6 to a surface area of at least 8000 m^2/m^3. The scientists expect that this approach will enable them to significantly improve the efficiency of adsorption pumps in comparison to existing solutions. This will also be supported by a thinner coating thickness and thus a lower thermal mass.

The project runs until 2017. The BMWi is funding this research with 2.6 million euros.

Recycle-To-Gas: material that can undergo pyrolysis as an energy source in lime works

Increasing energy prices and waste disposal are two significant cost drivers in many industrial sectors. In contrast, secondary energy sources, such as plastic that is utilised in lime works in their own specific plant technology, preserve fossil fuel resources and at the same time make the lime burning process more energy efficient. However, it has not been economically and technically effective to integrate these technologies up to now.

Fels-Werke GmbH in cooperation with the TU Clausthal focussed on this subject and developed the patented **ecoloop® process** that for the first time enables an ecological and economical solution for the generation of synthetic gas from residual materials in lime works. The BMWi funded this project with around 5.3 million euros.

The autothermic gasification of waste and residual materials instead of burning them offers the advantage of being able to reuse the carbon and hydrogen as synthetic gas in a highly efficient way. This can thus be used to generate thermal energy or be converted into electrical energy.

In the ecoloop® process, a new type of counterflow gasifier is activated upstream for energy-intensive processes at the lime works. This converts materials that contain high levels of carbon into hydrogen-rich synthetic gas by using coarse lime as a matrix in a moving-bed reactor without any mechanical components. The process is particularly environmentally friendly because organic and inorganic compounds such as dioxin or hydrogen chloride bind with the lime and are not released. Once the dust has been subsequently removed, the gas produced is available for internal or external thermal or material recycling. The discharged coarse lime is fed back into the process and thus closes the material loop of ecoloop®. The process is already being comprehensively tested by the project partners in large-scale technical pilot systems.

SPECIAL TOPIC

Energy efficiency in thermoelectrics

Electrical energy can be directly generated through differences in temperatures using thermoelectric generators. This harbours great potential because a high proportion of primary energy utilised in many industrial processes is still lost as waste heat. If this heat is recycled for the targeted purpose of generating energy, it is possible to make a valuable contribution to energy efficiency and to reducing CO_2 emissions.

However, the manufacture of the materials and the systems is still cost intensive and laborious. This is because the most advanced thermoelectric technologies come from space and military research and have not yet been adapted for mass production. The BMWi is thus supporting research projects that push forward large-scale technical demonstrations of this technology, increase the efficiency of thermoelectric materials and optimise the resource-saving use of materials.

The ThermoHEUSLER research project is, for example, developing a new manufacturing process for cost effective thermoelectric materials based on half-Heusler alloys. The project deals with alloy-type compounds, primarily made of transition metals, with complicated morphologies. And this is the reason for their high thermoelectric efficiency. Scientists recently succeeded in producing the n-type and p-type semiconductors required for the construction of thermoelectric modules using conventional foundry techniques and powder metallurgy processes on a kilogramme scale. The properties of the substances lie in the range of the best values published in literature (as of the beginning of 2014). The BMWi supported this joint project from Robert Bosch GmbH, the Fraunhofer Institute for Physical Measurement Techniques IPM, Johannes Gutenberg University Mainz, Augsburg University, Isabellenhütte Heusler GmbH & Co. KG and Vacuumschmelze GmbH & Co. KG with 2.5 million euros of funding. This project thus represented a major step towards industrial maturity.

INTEGA under harsh application conditions in the steel industry

State-of-the-art thermoelectric modules are inflexible, can only withstand limited mechanical stresses and mostly have to be produced by hand. The production costs are thus currently many euros per watt. The HighTEG research project is developing the prerequisites for cost-effective manufacturing processes for the mass production of thermoelectric generators with innovative properties based on their mechanical stability, flexibility and thus range of applications. This interdisciplinary consortium consisting of nine partners has received 6.6 million euros in funding from the BMWi. The following are involved in the project: Evonik Industries AG, MAHLE Behr GmbH & Co. KG, CeramTec GmbH, the special large-scale research funding initiative of the Karlsruhe Institute of Technology (KIT), the German Aerospace Center. (DLR), the Otto von Guericke University Magdeburg, Stiebel Eltron GmbH & Co. KG, LEONI Bordnetz-Systeme GmbH and the Bayerische Zentrum für angewandte Energieforschung e. V. (ZAE Bayern). The scientists developed processes in which thermoelectric materials can be introduced, for example, into ceramic moulds and special matrices. This has resulted in large-scale modules that can be produced by machinery with limited individually flexible forms.

Other research in this area includes the INTEGA project (Industrial Testing of Thermoelectric Generators for Power Generation from Waste Heat). This project aims to demonstrate that thermoelectric modules can be manufactured to be robust enough to meet the requirements for the harsh application conditions in the steel industry. The following companies are participating in the project: Salzgitter Flachstahl GmbH, Gentherm GmbH and VDEh-Betriebsforschungsinstitut GmbH. The BMWi is funding this project with 1.1 million euros.

Energy efficient recycling of titanium chips

The demand for titanium components in the aerospace industry has grown constantly in the last few years. One of the characteristics of titanium is the large amount of energy required for its primary extraction from the raw material. This accounts for around 85 percent of the overall energy requirements and CO_2 emissions in the process chain. In addition, chip removal rates of up to 95 percent are typical in the processing of titanium. The cost of the raw material itself is high and in Germany there is also a complete dependence on imports.

The aim of the **RETURN** joint project is to create a closed material cycle for titanium and thus to enable the recycling of at least 70 percent of the so far difficult to recycle or even non-recyclable titanium chips. The preparation of these chips should make it possible to sustainably increase the material and energy efficiency across the entire value added chain. In the process, the scientists aim to reduce the energy demand and CO_2 emissions by up to 55 percent. In addition, the project partners are investigating solutions for the provision of new energy efficient and cost effective processing technologies and a substantial reduction in the use of raw materials and resources.

Firstly, the scientists are evaluating the suitability of the titanium chips for recycling and analysing the ecological materials loop from a holistic perspective with the goal of generating potential for improvements. In the analysis, the researchers also take into account the interactions within the loop. By using new cooling lubricant strategies and adapted concepts for machine tools, the researchers aim to minimise the contamination of titanium waste in order to ensure the homogeneous sorting of the materials for the purposes of recycling. Furthermore, they aim to reduce tool wear and reduce gas absorption by the titanium chips using new cutting materials and geometries. This will be supplemented by new methods for cleaning, compacting and melting the chips, as well as by technically examining their semi-finished quality.

The BMWi is funding this project with around 1.6 million euros. The participants in the consortium include Leibniz Universität Hannover, MAG IAS GmbH, Deharde-Maschinenbau Helmut Hoffmann GmbH, VDM Metals GmbH and Walter AG.

Energy efficient CO_2 conversion using microreactors

The chemical industry offers broad scope for the development of innovative measures that can increase energy efficiency. The “Energy Efficient Electrochemistry in Microreactors” (**EnEl-Mi**) project involving Invenios Europe GmbH, Plinke GmbH and the University of Stuttgart is dedicated to the field of CO_2 conversion. The BMWi funded this project with around 910,000 euros.

The scientists want to develop microreactors and concepts for separating substances in the electrochemical reduction of CO_2 in flue gasses from production processes. Base chemicals such as formic acid, aldehydes and alcohols are produced from the carbon dioxide in this preferably continuous reaction process. The thermodynamically useless carbon dioxide in the flue gases can thus be converted into pure C_1 and C_2 carbon building blocks in the form of high value organic compounds. This can reduce the use of other fossil carbon in chemical production. The reaction cells in the microreactor have a volume of only a few millilitres which allows a capillary action to take place – a special feature of these types of cells. The capillary action can be utilised to separate substances and transport gas while special surface effects ensure the inert carbon dioxide will be activated. This is possible because these miniature reactors allow microscopic effects to occur that, in contrast to large reactors, do not get obscured by macroscopic effects.

Another special feature of the reaction process is the use of modified gas diffusion electrodes. These increase the solubility of the CO_2 and minimise problems that can reduce the yield such as overpotential, as well as helping to reduce diffusion-limiting kinetic effects.

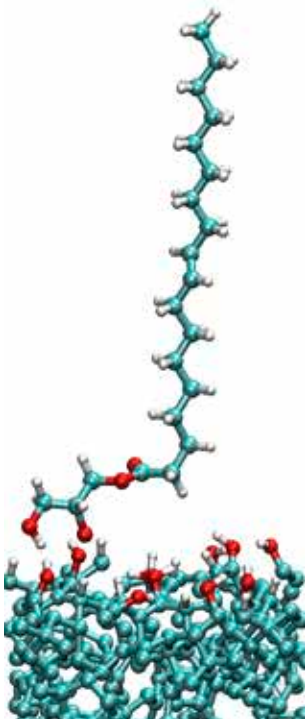
This approach is ambitious because these kinds of micro processing technologies have not previously been applied to electrochemical processes and the conversion of large volumes of substances. The conclusion of the project has now led to the creation of a technical concept that will allow the construction of smaller demonstration plants in order to prove their suitability for bypass operation in real production processes.

Energy efficiency in mechanical engineering through lower friction

Friction is a constant effect that occurs between machine components that move relative to each other. This causes wear and additional energy consumption. A significant proportion of the fuel consumption in motor vehicles can be traced back to overcoming the effects of friction. As usual sources of potential for reducing friction have already been exhausted from a technical standpoint, research into tribology is breaking new ground: diamond-like carbon coatings (DLC) for drive systems with special lubricants which achieve superlubricity and thus drastically reduced levels of friction in comparison to all other known variants. At the same time, the DLC coating has anti-corrosive characteristics, is extremely hard and thus has the potential to further reduce wear.

Two joint projects being funded by the BMWi are currently focussing on this topic. The Poseidon project is investigating the tribo-corrosive effects of these and other coatings such as corrosion-resistant steel materials in corresponding media – for example, pumps in the food and chemical industries or in sea water. The liquid already available in these kinds of environments should ideally act as a lubricant (media lubricant) and thus make other sealing components – which generate additional friction losses – obsolete. The consortium is being coordinated by the Stiftung Institut für Werkstofftechnik (IWT Bremen). Other partners are Schaeffler Technologies GmbH & Co. KG, the Fraunhofer Institute for Computer Graphics Research IGD, Deutsche Edelstahlwerke GmbH, the Ruhr University Bochum and Energietechnik Essen GmbH.

The Pegasus project aims to harness the effect of superlubricity for the automobile sector through the use of diamond-like carbon coatings and special lubricant components. In order to scale up this principle for the mass production of complex, heterogeneous systems with a wide variety of frictional pairings (e.g. in the drive trains of passenger cars), future superlubricity lubricants need to be adapted to both the new coatings and also traditional steel surfaces. This demands the most detailed and fundamental understanding of all the tribological interactions in the interface of a tribo-system. The transfer of this technology to a new type of coating plant for large production quantities was already successfully achieved in the predecessor project Pegasus I. The current consortium is examining other fundamental issues in the follow-up project Pegasus II. The consortium is made up of the partners BMW AG, Fraunhofer Institute for Material and Beam Technology IWS, Freudenberg Sealing Technologies GmbH & Co. KG, VTD Vakuumtechnik Dresden GmbH, Bosch Rexroth AG, Schaeffler Technologies GmbH & Co. KG, FUCHS Europe Schmierstoffe GmbH, Bosch Mahle Turbo Systems GmbH & Co. KG and ZF FRIEDRICHSHAFEN AG.



Physisorption of a glycerine monooleate on a tetrahedral, amorphous carbon surface (GMO on ta-C) in the Pegasus project

SPECIAL TOPIC

Energy efficiency and process acceleration in the chemical industry

The chemical industry is particularly resource and energy intensive. Therefore, measures that improve energy efficiency or accelerate processes and optimise operating costs will be particularly effective. Four consortiums and an individual project are conducting research within the ENPRO initiative. The BMWi is funding these activities with around 7 million euros.

ENPRO stands for energy efficiency and process acceleration within the chemical industry. The aim is the transfer of new products from the laboratory to industrial production more quickly, and more efficiently in terms of energy and resources. All steps in a chemical production process (from the chemical reactions through to the processing of products) need to be modular to allow them to be continuously replaced and upgraded. At the same time, they should also be designed to allow the compatible networking of data between them.

This should make production energy efficient and highly flexible for any possible adjustments that might need to be made to the production volumes.

The KoPPonA joint project is dedicated to developing new, energy efficient, continuous production processes for special polymers using innovative concepts for the apparatus, which can be easily scaled up for industrial production. The researchers are developing and testing milli-structured reactors and apparatus for the development of products on a laboratory scale, whose performance characteristics can be directly transferred to large production plants in the future. The participants in the project include BASF SE, Ehrfeld Mikrotechnik BTS GmbH, Ruhr University Bochum, RWTH Aachen and the University of Stuttgart.

The SMekT (Smart Miniplants for the Development of Efficient Separation Processes) consortium including Evonik Industries AG, HiTec Zang GmbH, SONOTEC Ultraschallsensorik Halle GmbH, the Karlsruhe Institute of Technology (KIT) and the TU Dortmund is conducting research into separating processes. These processes are often only carried out on a batch basis and are significantly less efficient than comparable, continuously operating production plants. The aim is to develop a scalable process that removes solid materials with different levels of moisture via a continuous crystallisation process in a reaction system.

In the third consortium, Evonik Industries AG, Lewa GmbH, Netzsch GmbH, TU Dortmund, the University of Erlangen, Siemens AG, DBIC GmbH, Benken GmbH, plantIng GmbH and qonqave GmbH are developing modular tools for chemical production. The aim is to create standardised key components for technical processing plants in order to ensure the more energy efficient and resource efficient planning of these plants. A consortium consisting of BASF SE, Evonik Industries AG, Bayer Technology Services GmbH, AixCAPE e. V. and RWTH Aachen has dedicated itself to speeding up processes through data integration and dismantling information barriers along the value added chain, from the development of the process itself through to the finished plant.

DECHEMA e.V. is developing the scientific “clamp” that lies at the heart of this consortium with the ENPRO Connect exchange programme. It promotes the networking and exchange of information within the initiative and with other companies and research institutions to guarantee the easy transfer of results.

HIGHLIGHT

ETA-Factory: energy efficient manufacturing of the future

For companies that follow the goal of operational excellence, resource efficiency is also an integral part of their strategy. This is because the efficient use of energy is an increasingly significant factor for the achievement of corporate goals. In addition, energy efficiency offers great potential for making economically viable savings – not least due to increasing energy costs. As the ideas for optimising individual processes have been largely exhausted, decision-makers now need to turn their attention to energy-related interrelationships in order to make a real impact.

This subject is the focus of an interdisciplinary consortium of 6 funded and around 20 associated partners from the areas of industry and science, coordinated by the Institute of Production Management, Technology and Machine Tools (PTW) at the TU Darmstadt. The highly efficient **"ETA-Factory"** is being developed as part of one of the research projects. ETA stands for the centre for Energy efficiency, Technology and Application. By holistically observing and optimising a typical process chain in the metal processing industry in combination with the technical building equipment and factory building itself, the scientists involved in the project aim to reduce energy consumption by up to 40 percent.

The holistic approach being adopted by the consortium represents a fundamentally new way of thinking because although there were already many approaches for developing energy efficient production technologies these tended to result in isolated individual solutions. Alongside the improvement of subprocesses within the overall system, the ETA research partners from the areas of mechanical engineering, structural engineering and architecture are thus investigating, in close cooperation with industry, an industrial production chain in combination with technical building equipment and the factory building itself, and are developing it further with a focus on improving overall efficiency.

In addition to networking the subsystems, the intelligent and uniform management and control of the electrical and thermal energy flows along the production chain and their interaction with the building shell is another significant focus of the work. As a result of the

proficient control and networking of sources and sinks of waste heat and the optimisation of the individual process steps, it has already been possible to demonstrate significant energy savings.

The foundation stone was laid at the site of the TU Darmstadt on 12 August 2014 and thus an important step was taken on the road to the energy efficient model factory. The process chain for the production of a hydraulic pump component for the ETA partner Bosch Rexroth AG is being used as a reference process and will be reproduced and optimised in the factory. The factory will be built in 2015 and the model production process constructed. The official commissioning of the factory is planned for early 2016. The demonstration factory aims to illustrate the research results in application and should act as the nucleus for further technological and efficiency-related innovations. The results will be utilised to great advantage. This is assured by the fact that they will form an anchor for the scientific teaching on-site. The engaged circle of associated industrial partners should also ensure that the findings are utilised far beyond the boundaries of the project.

Computer simulation of the ETA-Factory building

Combined generation of heat and electricity

Selected funded projects

EnEff:Wärme: ORC processes with new turbo generators for the efficient conversion of waste heat into electricity

Organic Rankine Cycle (ORC) processes can be used to generate electricity suitable for the baseload from waste heat. New types of steam turbines that use steam from organic working materials are deployed here. In a research project run by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, three ORC processes for combined heat and power plants (CHP) were developed with a power output of between 400 and 1500 kW. This included one process for up to 40 kWel for cooling water heat conversion and two processes with a maximum of 60 and 120 kWel for the conversion of waste heat from engines into electrical power. All three processes were tested in a follow-up project in a field test, where scientists set up seven ORC plants at six locations, optimised the ORC modules and subsequently monitored their performance, allowing the continuous optimisation of their efficiency, reliability and system costs. The BMWi funded both projects with a total of 3.1 million euros.

The projects enabled the scientists to generate electricity from unused waste gas and cooling water heat from engines in the CHPs – which has positive effects on the energy balance of the plants. The ORC process for converting waste heat into power provides up to 12 percent additional electrical output depending on the availability of the waste heat, while the ORC process for utilising the cooling water heat delivers up to 5 percent additional power, depending on the original power output of the engine. It was possible to verify the expected efficiency in electricity generation of 18 percent for waste heat and 7 percent for engine heat. Therefore, the projects offer the potential for the realisation of decentralised engine and steam turbine power plants with an overall electrical efficiency of up to 50 percent. Nevertheless, further research and pilot applications are required before the technology reaches market maturity. The required field tests will be implemented by Fraunhofer UMSICHT by the early summer of 2016 in a demonstration project.

Systems analysis and cross-cutting issues in the energy transition

The goals of the German federal government to halve primary energy consumption by 2050 and increase the proportion of energy generated by renewable energies to 60 percent are unparalleled worldwide. The fundamental restructuring of the energy system required for the achievement of these goals is thus lacking examples and experience from other countries as a result. Systems analysis could contribute to closing these gaps in our knowledge. Therefore, quantitative models are being developed and implemented that simulate and evaluate the macroeconomic effects of potential developments in the energy system. This work is being supplemented by research into cross-cutting issues, such as the role of political framework conditions.

Market developments in Germany and across the world

The already emerging change in the energy system is characterised by an increasing number of market participants and players. The proportion of decentralised electricity generation plants is increasing constantly with the expansion of photovoltaics, wind power and biomass energy. Hub Stations for the combined generation of heat and electricity and for the (decentralised) storage of electricity and heat mean that the electricity and heating markets are becoming increasingly interlinked. Innovative technologies for electrolysis make it possible, for example, to create methane from excess renewable electricity via the production of hydrogen. Methane is a compound that can be stored for long periods in the natural gas network and utilised in the heating markets and transport sector. Moreover, information and communication technologies make it possible for energy consumption to be managed based on the availability of renewable energies. This is supplemented by all aspects of energy efficiency that require the implementation of a diverse range of measures in private households, medium-sized companies, the transport sector, buildings or large-scale industry.

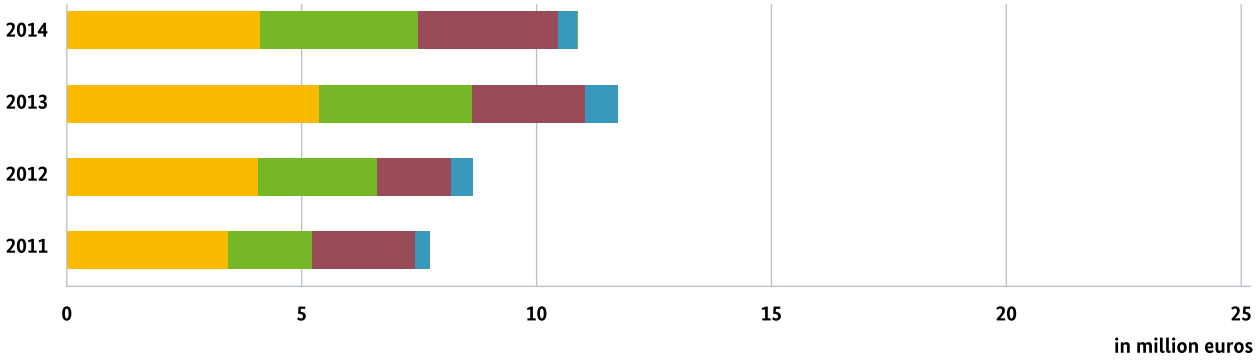
Progress in research and development

The ever more complex interrelationships in the energy industry can be modelled with the aid of systems analysis

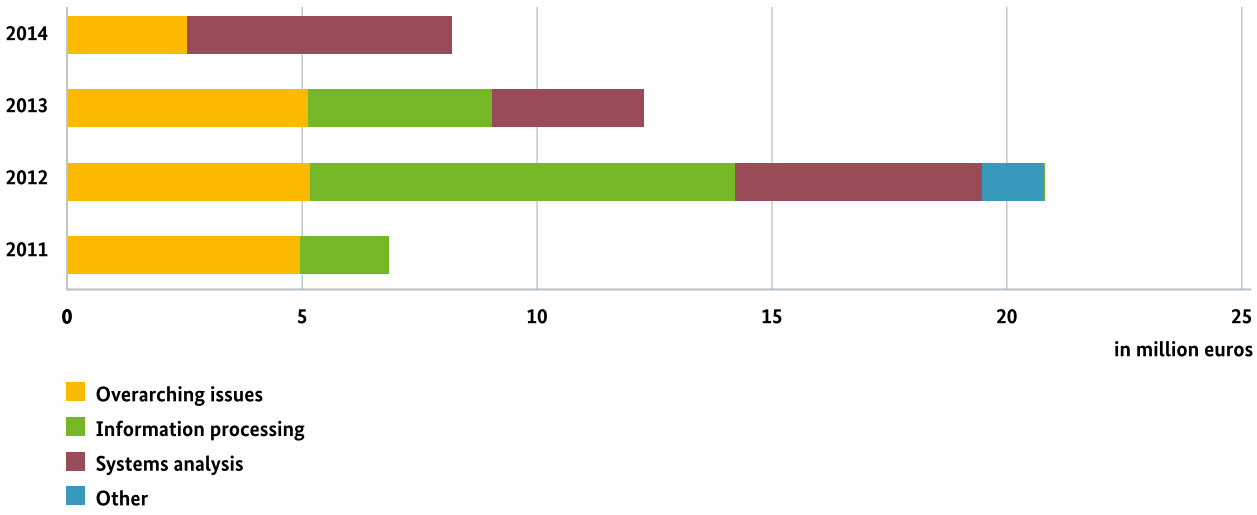
so that the effects of energy policy measures can be examined in advance. The dependency on technological developments and the interplay and competition between technologies can also be simulated and evaluated based on the implications for research policy. However, the development of methods and tools for carrying out systems analysis, i.e. the models themselves, are also a matter for research funding. The models are thus continuously adapted to current developments in the energy industry and updated to include new mathematical, economic and IT methods. Energy industry and political scenarios that stretch far into the future can also be investigated and evaluated. For example, the **ReWal – Reserve Markets in Transition** research project focuses on the anticipated developments in the provision of electricity from fluctuating sources and the resulting demand for reserve power plants. Market mechanisms will be investigated on this basis that guarantee an inexpensive provision of energy in the operating reserve and thus can support politicians to design suitable framework conditions for the future.

The examination of these cross-cutting issues is also making a contribution to ensuring that the energy transition as a whole can be successfully implemented. The results provide the necessary basis for carrying out systems analysis studies for decision-makers. One such study called "Roadmap Speicher" (Storage Roadmap) has revealed that the further expansion of renewable energies does not need

Systems analysis and cross-cutting issues in the Energiewende: Distribution of funding between 2011 and 2014



Systems analysis and cross-cutting issues in the Energiewende: Trend in the volume of newly approved funding since 2011



to wait for the expansion of storage systems: Load management measures or the exchange of electricity, either nationally or across Europe, is still sufficient to compensate for fluctuating generation from wind power and solar energy until the proportion of energy generation accounted for by renewable energies reaches 60 percent.

Strategy for research funding

The Federal Ministry for Economic Affairs and Energy initiated a consultation process in 2014 for the establishment of a research network called "Energy Systems Analysis" that is designed to contribute to the identification of new areas of focus for research funding within the field of systems analysis and to create opportunities for cooperation. Central themes are thus, amongst other things, the comparability and transparency of results from models, the creation of uniform reference datasets and the integration of social science research work into the models. Measures to increase scientific quality through sensitivity analyses and parameter studies, new algorithms and the use of mainframe computers, as well as work to subdivide the models into modules and to standardise interfaces, will also be part of future research work.

In 2014, around 6.5 million euros was provided as funding to ongoing research projects in the area of systems analysis (2013: around 6 million euros). There were 7 newly approved projects with a total funding volume of 2.2 million euros in 2014 (2013: 16 projects with 7.1 million euros).

The "Statement on the funding of research into cross-cutting issues related to the overall strategy for the further expansion of renewable energies", published on 2 August 2013 by the BMU and continued by the BMWi, places the focus on the development of suitable political, legal, economic, social and ecological framework conditions for the energy transition. The interaction of all social forces will be examined here. Amongst other things, the role of state decisions will be examined in a learning system. How can the strategies for planning and decision making be developed when it is not yet possible to precisely predict all of the long-term parameters? Another important focus of the funding statement were cross-sector considerations in which electricity, heating and transport are examined together or the interplay between energy generation and energy efficiency is also taken into account. The role of the market, as well as the special challenges faced in the heating market, are other aspects that need investigating.

The funding provided to ongoing projects in the area of cross-cutting issues and systems analysis totalled around 10.8 million euros in 2014 (2013: around 11.7 million). In addition, there were 26 newly approved projects with a total funding volume of 8.2 million euros in 2014 (2013: 12.2 million euros).

Solar power plants are one of the visible indicators of the increasing proportion of renewable energies in the German energy supply system

SPECIAL TOPIC

BINE Information Service: At the cutting edge of energy research

The BINE Information Service has been reporting on research projects in the area of energy research for many years. In the following interview, the Head of Department Jutta Perl-Mai spoke, amongst other things, about changes in media consumption and the role the BINE Information Service has assumed.

What themes does the BINE Information Service cover? What products are offered in this context?
Perl-Mai: The BINE Information Service – energy research for practical application – covers the whole spectrum of non-nuclear energy research funded by the Federal Ministry for Economic Affairs and Energy, from renewable energies through to energy efficient technologies. We provide a broad portfolio of electronic and printed media, from the presentation of individual research projects through to thematic research portals, which can be subscribed to or accessed individually free of charge. This is supplemented by additional information such as the dates of events, addresses of project partners and further links and information from the field of research. Our research newsletter reports once or twice a week on the latest research highlights. This keeps our readers up-to-date on new or planned developments.

What is the target group for the BINE Information Service?
Perl-Mai: Professional groups that are involved with energy applications, energy technology, energy consulting or energy research are our most important target group. In addition, we provide information to training and further education institutions and specialist media.

What differentiates BINE Information Service from other specialist media?
Perl-Mai: We exclusively place the focus on energy research by the German federal government and are funded by the BMWi. Due to the close cooperation with the BMWi and Project Management Jülich, we can promptly provide up-to-date, relevant findings from the field of energy research that have been thoroughly scrutinised and prepared specifically for our target group.

Jutta Perl-Mai, Editor-in-Chief of the BINE Information Service

The energy transition is extremely complex as a major social project. How do you see the role of the media and the BINE Information Service in this context?
Perl-Mai: As an independent information partner for energy research, the role of the BINE Information Service is clearly defined as a partner in a network of different providers of information on the subject of energy. Our information service makes a contribution to the achievement of the energy transition by providing information from the field of research and thus supporting these innovative technologies on their path to the market

Since the start of the BINE Information Service, the consumption of media in society has changed drastically. How are you adapting to these changes?
Perl-Mai: We have placed an increasing focus on providing information in an electronic form during the last few years. All printed information publications can thus also be subscribed to digitally. The BINE newsletter has been very well received and currently has over 16,000 subscribers. The research portals covering the different key thematic areas, which have been continuously expanded and operated since 2006, have also achieved very promising numbers of visitors.
We are currently developing innovative strategies for social media such as Twitter, Facebook and Google+ in order to bring our content to a new generation of users.

What new themes or products are you planning in the near future?
Perl-Mai: Alongside the already existing research portals, which are being consistently enhanced and whose content is being constantly updated to take account of the requirements of the target groups, we are currently working on expanding the research network maintained by the BMWi and supporting it in the area of research communication.

SPECIAL TOPIC

EnArgus: Transparency in energy research

The success of the energy transition is closely connected to the acceptance it receives from all stakeholders in the areas of politics, business and industry, research and development, as well as citizens. Therefore, an important goal of the German federal government's 6th Energy Research Programme is to increase the transparency of all state funding policies for all stakeholders and at the same time to take the knowledge from completed research projects and make it accessible using the latest methods for information research.

The EnArgus project funded by the BMWi is developing a central information system using software that will provide politicians, the project managers and interested members of the public with uniform and central access to the energy research environment in Germany and will give an overview of all of the approximately 22,000 projects. In addition, around 2,000 Wiki articles will provide information on the range of energy themes funded by the BMWi. The information will also be prepared retrospectively back to when electronic filing started so that all projects since 1976 can be researched. The system is due to be completely implemented by the end of 2016.

EnArgus is a joint project involving scientists from the areas of energy research and computer sciences. On the IT side, participants in the project include the Fraunhofer Institutes FIT and FKIE, as well as the KMU OrbiTeam. The energy expertise is provided by the Fraunhofer Institutes UMSICHT and ISI, the Research Group for Energy Systems and Energy Economics (LEE) at the Ruhr University Bochum, the Institute IWAR at the Darmstadt University of Technology (which deals with water supply and groundwater protection, wastewater technology, waste technology, industrial material cycles, spatial and infrastructure planning), the Materials Testing Institute of the University of Stuttgart (MPA Stuttgart), Otto-Graf-Institut (FMPA), the ZEDO Centre at the Technical University of Dortmund (which deals with consulting systems in technology), and, in the first phase of the project, the Institute of Energy and Climate Research – Systems Analysis and Technology Evaluation at Forschungszentrum Jülich.

The EnArgus software solution is made up of two parts. Firstly, a website for general access including the recipients of funding from the German federal government. And secondly, an internal system requiring access rights that contains the entire pool of specialist information on the funded projects and is directed towards the special requirements of Ministers and project managers. No new data will be compiled in EnArgus but instead already existing information will be collected together from different sources. This work will involve using the Profi platform (Project Funding Information System) operated by the Federal Ministry of Education and Research. As a result of the automatic consideration of technical relationships within the system, users without detailed knowledge will also be able to carry out targeted research – depending on their access rights.

Once the project has been completed, Project Management Jülich will operate EnArgus on behalf of the BMWi. The stored specialist content will be subject to the strictest data protection regulations.

Further information can be found on the website: https://enargus.fit.fraunhofer.de/

Screenshot showing Argus

Selected funded projects

Optimising the decentralised use of electricity and heat

As a result of the expansion of fluctuating renewable energies, situations will increasingly arise in the future in which more electricity from wind and photovoltaics is available than is actually required at that point in time. In order to ensure this electricity is used as economically and sustainably as possible, it may prove wise to combine it with heat generation and cooling. Heat generation and cooling will thus be integrated to a greater extent in future into the electricity sector, for example through the use of electric heat pumps or intelligent air conditioning systems.

The goal of the **PowerFlex-Heat-Cold** research project is to integrate the heating and cooling sector into models for the electricity market and to investigate their interactions in detail. For this purpose, the Öko-Institut e. V. is further developing its electricity market model PowerFlex that was developed in previous projects. The expanded model aims to demonstrate the synergies, interactions and competition between the sectors. For example, the scientists can investigate how renewable energies can be economically and sustainably integrated into the market, how much electricity from renewable power sources is required for the heating and cooling sectors to achieve the climate protection targets and what effects the new flexibility options could have on reducing electricity prices. The BMWi is funding the PowerFlex-Heat-Cold project with around 350,000 euros.

In the **STROWAE** project, the Fraunhofer Institute for Solar Energy Systems ISE is developing and analysing a new market role for the best possible management and optimal expansion of the distribution grid. As part of the modelling of this *Decentralized Market Agent*, a particular focus is being placed on integrating the combined generation of heat and electricity, heat storage and efficient heating technologies. The scientists thus aim to reveal new possibilities for the economical combination of electricity and heat at a distribution grid level through the new market role and how these closer links will be able to contribute to ensuring the stability of the electricity grids.

The BMWi is funding the project with around 500,000 euros.

Systems analysis

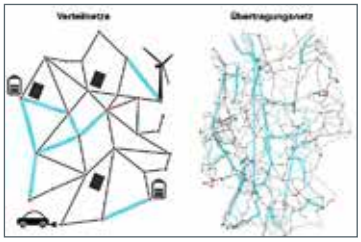
Selected funded projects

Operating reserve markets in transition

Transmission grid operators stabilise and maintain the frequency of the electricity grid using the operating reserve. This output is provided through market-based processes on operating reserve markets from generation plants. Due to the increase in renewable energies, grid operators will have to maintain even more output that will be called on more and more frequently. These increased requirements make structural reforms necessary. In an analysis of the design of the energy market, the Center for European Economic Research (ZEW) and the Institute of Power Systems and Power Economics (IAEW) at the RWTH Aachen are conducting research into new concepts for this transitional system.

The project, which has been provided with 527,000 euros of funding by the BMWi, is evaluating the effectiveness and efficiency of currently utilised tools and the technical, economic and regulatory challenges faced by the operating reserve market and the supply system itself. In addition, scientists are investigating the possible effects of increased feed-ins from renewable energies on system security and the security of supply and the operating reserve markets. The design of operating reserve products, demand in future, the interaction between different markets and the design of auctions play an important role in this area. For this reason, discussions and analyses of a possible market design for operating reserve energy in combination with the spot markets are being carried out as part of this project.

Furthermore, the partners are conducting a technical and economic analysis of the potential and impact of a European integration of the operating reserve markets and the wholesale electricity markets with the help of a market model. The basis for this model is formed by data about generation and capacity and very comprehensive forecasts of the feed-in volumes from wind and photovoltaic power plants. Other economic tests on strategic behaviour and the potential for the abuse of market power are based on day-ahead prices and intraday prices, the volumes of operating reserves available and operating reserve prices, the demand for balancing energy and its prices and the operating reserve balances.



The MONA 2030 project compares different measures for relieving the burden on the transmission and distributions grids

Merit order grid expansion 2030

The positive development in the expansion of renewable energies is placing great demands on the grid infrastructure due to its decentralised and volatile character. Previous strategies to adapt the transmission grid to this technical change through constant small enhancements are no longer sufficient. The FfE Research Center for Energy Economics has dedicated itself to this subject and is investigating different measures and scenarios for minimising the expansion of the grids in the "Merit order grid expansion 2030" (MONA 2030) project. The project is part of the "Future-Oriented Electricity Grids" funding initiative and started in October 2014. The BMWi is funding this project with 1.5 million euros over a period of three years. The FfE is being supported by an advisory board consisting of 16 partners from the areas of energy supply, energy transmission, energy distribution and industry.

The focus is being placed on the evaluation and comparison of existing and also future options for the design of the grids in Germany. This should provide the basis for the planning of a forward-looking and holistic grid. In particular, the scientists want to investigate technologies and measures for relieving the burden on the transmission and distribution grids, above all with a focus on the supply of higher proportions of electricity from renewable energies. The participants in the project are taking the Merit Order conventional power plants as a role model here. Merit order in a traditional sense refers to the deployment sequence of power plants. This is determined according to the marginal costs of the electricity generation. Starting with the lowest marginal costs, power plants with higher marginal costs are deployed in sequence until the demand is covered. In the MONA 2030 project this term has been utilised to describe measures for relieving the burden on the grids. In particular, the investment decisions that must be made in relation to these measures are being taken into account. In order to develop a valid basis for evaluating this relief to the grids despite the diverse range of grid and supply structures, the scientists aim to classify types of grids and regional load profiles, which will then serve as the starting point for a comprehensive simulation model at a grid level.

Developing energy strategy

Selected funded projects

Systems analysis for energy storage

Energy storage systems have a strategically decisive role to play in the energy transition. And there are also a number of superordinate, systemic issues. The thematic consortium "Systems analysis for energy storage" has five projects dedicated to these issues in the "Energy storage" research initiative. The BMWi is funding this research with around three million euros.

In this context, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM is analysing measures for balancing inflexible electricity generation with a combination of electricity, gas and heat supplies in comparison to other buffer options in the "Multi-Grid-Storage (MuGriSto)" project. In the "Merit Order for Energy Storage in 2030" project, the Forschungsstelle für Energiewirtschaft e. V. (FfE) is investigating technical variants, fields of application, application mechanisms and scenarios for functional electricity storage systems. The Institute of Energy Economics at the University of Cologne is dedicated to conducting economic and scientific research into the different technological approaches in the overall system. The University of Duisburg-Essen is investigating stochastic methods for managing and evaluating centralised and decentralised storage systems in the context of the future energy system for Germany. In its "Systems analysis for energy storage" project, the Institute for Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart is carrying out a systems analysis of energy storage technologies in Germany and Europe from an energy industry perspective to support the integration of renewable energies. In addition, the scientists at the IER are further developing energy system and electricity market models to depict various storage options.

The five projects are cooperating with each other to research and process data, discuss joint scenarios and their framework conditions and harmonise their efforts.

Cross-cutting issues in the energy transition

HIGHLIGHT

How much storage capacity will we need in the future?

Following the expansion of generation plants to include fluctuating wind and solar energy, the need to balance generation and consumption has also become more urgent. In the "Roadmap Speicher" (Storage Roadmap) research project, scientists have analysed the future demand for additional electricity storage systems based on technical and economic aspects and investigated the legal issues related to their use.

The study shows that the expansion of renewable energies in Germany can continue to be rapidly implemented. This is because load management and the exchange of electricity at a national and European level will provide sufficient flexibility until renewable energies have expanded to account for 60 percent of electricity generation. There is still time until then, according to the study, to establish the required storage technologies. Even if renewable energies accounted for up to 88 percent of electricity generation, it would still be largely possible to do without additional electricity storage if greater flexibility is achieved from a load and generation perspective. However, in the case of limited flexibility in electricity generation and a failure to simultaneously integrate alternative flexibility options, the study identifies a long-term requirement for additional electricity storage.

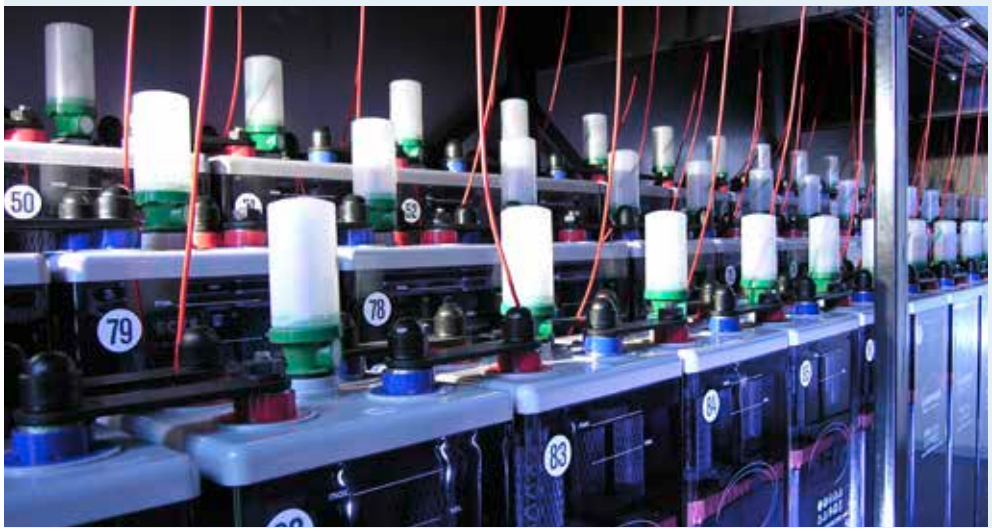
The electricity supply system of the future must, above all, be designed to be flexible, according to the results of the study. This flexibility could already be achieved to a large extent through the expansion of the grids, the European electricity market and load management, flexible biogas plants, the combined generation of heat and electricity or power-to-heat. The integration of higher proportions of renewable energies into the electricity system would be possible in this way without additional electricity storage, although it would be particularly dependent on the expansion of the grids and what load management measures were in place.

In addition, the study demonstrates that additional daily storage systems would be required if there were higher proportions of fluctuating wind and photovoltaic electricity. At the same time, an increasing number of system services need to be provided in the future, whereby electricity storage systems could make a contribution.

In order for these storage systems to be operated economically, it is necessary to significantly reduce their costs. There is also the problem of their high loss in efficiency. Therefore, scientists recommend the direct use of the electricity as far as possible for economic and climate policy reasons.

The project was coordinated by the Fraunhofer Institute for Wind Energy and Energy System Technology IWES and conducted in cooperation with the RWTH Aachen and the Stiftung Umweltenergierecht.

The BMWi funded the "Roadmap Speicher" project with around 800,000 euros.



In the "Roadmap Speicher" (Storage Roadmap) research project, scientists have analysed the future demand for additional electricity storage systems based on technical and economic aspects and investigated the legal issues related to their use

International cooperation

Climate change has clearly shown that the associated global challenges for limiting global warming through low carbon emission energy technologies and preserving fossil fuel resources in the generation of power can only be resolved with comprehensive cooperation between countries. In the context of the energy transition, intensive international cooperation is accordingly a strategic pillar for the German federal government.

Germany is cooperating with other countries, on the one hand, at a European Union level or through the ERA-NETs (European Research Area Networks), which support cooperation between national and regional research funding institutions. On the other hand, the German federal government is also active on a global level through the Federal Ministry for Economic Affairs and Energy, for example through its engagement in the International Energy Agency (IEA). The IEA is a globally important cooperation platform for research, development, market launches and applications in the area of energy technologies.

Funding and distribution of low CO_2 energy technologies in the European Union

The European Union and its member states have committed themselves at a variety of levels to climate protection and a resource conserving, forward-thinking energy policy. An important goal is to implement measures at a pan-European level that will help to limit global warming to below two degrees Celsius. Furthermore, future-oriented energy technologies contribute to the security of supply in the European Union and retain the competitiveness of European companies.

An important tool for the future-oriented energy policy of the European Union is the European Strategic Energy Technology Plan (SET-Plan). This was created in 2008 and promotes the development and dissemination of low carbon technologies while taking into account aspects of competi-

tiveness and economic efficiency. The SET-Plan aims to develop cost effective and low emission energy technologies in the long term and implement them in the member states of the European Union so that greenhouse gas emissions in the EU can be reduced by 80 to 95 percent by 2050 in comparison to 1990. The plan comprises measures for planning, implementation, resources and international cooperation. The SET-Plan is thus following the "Energy Roadmap 2050", which the European Commission approved in December 2011. The European Union also aims to use this strategy plan to promote efficient and targeted energy research. This approach will help to prevent the duplication of research funding, accelerate innovations and better utilise the economic potential within the EU internal market.

In the short term, the SET-Plan is following the guidelines set out in the climate and energy package that was agreed by the EU states in 2008 as the so-called 20-20-20 targets. On the one hand, these targets envisage a reduction in European-wide CO_2 emissions by 2020 of at least 20 percent compared to the levels in 1990. On the other hand, the targets also include binding agreements for an increase in the use of renewable energy sources, such as wind, solar and biomass, to at least 20 percent of the overall energy production. Furthermore, energy consumption within the European Union is to be reduced by 20 percent compared to the levels forecast for 2020 by improving energy efficiency.

The implementation of the SET-Plan is based on two important instruments: The European Industrial Initiatives (EII) and the European Energy Research Alliance (EERA). The strategic planning and long-term implementation of the stated goals in the Technology Roadmap for the SET-Plan and the Integrated Roadmap (IR) are the responsibility of the SET-Plan Steering Group.

SET-Plan Steering Group and Integrated Roadmap

The Steering Group is comprised of representatives from the EU member states, Norway, Switzerland and Turkey under the leadership of the European Commission. Its role is to achieve efficient harmonisation and to act as the coordinating body for the implementation of the SET-Plan. In addition, the Steering Group develops and supports joint European measures, identifies resources for financing planned activities and monitors their progress. Germany is represented by the BMWi on the Steering Group.

Work on the Integrated Roadmap for the SET-Plan, which was carried out by a series of experts under the leadership of the Steering Group, was completed at the end of 2014. Following the completion of this work, the European Commission started to develop an action plan that contains an overview of those activities by EU member states that are relevant to the SET-Plan and reflects the possible thematic responsibilities of the countries and the resulting possibilities for cooperation.

SET-Plan Information System (SETIS)

The Steering Group for the EU SET-Plan is supported by the SETIS information system. SETIS stands for European Strategic Energy Technology Information System. It follows the development of key technologies in the energy sector and enables the evaluation of different technological options and priorities, monitors the progress of the implementation of the SET-Plan, estimates the consequences for European energy policy and on this basis can – where necessary – recommend corrective measures. For this, SETIS has been used to compile key performance indicators (KPI) in cooperation with the European Industrial Initiatives (EII) to enable the valid measurement of results. SETIS provides an overview of all activities conducted as part of the SET-Plan in relation to European research funding, draws attention to other development potential and indicates possible obstacles in the market launch of new energy technologies.

European Industrial Initiatives (EII)

The short-term implementation of the SET-Plan based on the thematic Implementation Plan lies in the hands of the European Industrial Initiatives. The goal of the EIIs is to bring together the work being carried out by the European Community, the member states of the European Union and industry in order to achieve common goals and create a critical mass of activities and players. This will strengthen energy research and innovation dealing with those types of technologies that deliver high added value to the European Community. The strong participation of industry partners in energy research and demonstration projects accelerates the innovation process and promotes the development of low CO_2 energy technologies. In addition, the EIIs provide suggestions for future funding in the area of energy research as part of the European Framework

Programme for Research and Innovation – Horizon 2020.

The following European Industry Initiatives are currently active:

- European Wind Initiative (EWI)
- Solar European Industrial Initiative (SEII; Photovoltaics and Thermo-Solar)
- European Industrial Bioenergy Initiative (EIBI)
- European CO_2-Capture, Transport and Storage Initiative (CCS)
- European Electricity Grid Initiative (EEGI)
- European Sustainable Nuclear Initiative (ESNII)
- Smart Cities (Energy Efficiency – The Smart Cities Initiative)

and two further initiatives:

- Fuel Cell and Hydrogen Joint Technology Initiative (FCH JTI)
- Nuclear Fusion (International + Community Programme – ITER)

European Energy Research Alliance (EERA)

The European Energy Research Alliance promotes the improved coordination and cooperation between research centres and universities as part of Joint Programmes (JP). It was founded by leading European research institutions and aims to accelerate the process for taking new energy technologies from idea to market maturity. Through the alliance, research activities within the European Union should become more effective by avoiding any overlaps. By combining national and EU research funding, it should be possible to create synergies and complementarity for the achievement of the SET-Plan targets. EERA brings together knowledge from more than 2,700 scientists from around 150 institutions and organisations. These scientists currently work together on 15 research programmes.

International research cooperation as part of the SET-Plan

Another significant focus of the SET-Plan is to promote international cooperation at the level of energy research. This aims, on the one hand, to develop a network of scientists primarily with the European Union but also, on the other hand, to promote cooperation with research centres, universities and companies worldwide including institutions in developing and emerging countries. The aim is to improve access to low CO_2 energy technologies worldwide and thus support the achievement of climate protection targets.

SPECIAL TOPIC

The Berlin Model for project funding

In the following interview, Dr. Georg Menzen, Head of the Energy Research Department and Project Funding at the German Federal Ministry for Economic Affairs and Energy provides an insight into the Berlin Model for project funding as part of the European Union's Strategic Energy Technology Plan for promoting low CO_2 energy technologies.

Dr. Menzen, what exactly does the term "Berlin Model" mean?
Menzen: The Berlin Model serves for the efficient implementation of the SET-Plan. It involves a three-step process which helps to identify, coordinate and implement joint projects between the member states.

What does this mean in concrete terms for project applicants?
Menzen: The application process for multinational projects is becoming more straightforward. The first step is the development of the joint binational or multinational project idea. From this, a draft proposal is created that the partners then present to their relevant national funding institutions. Once the draft proposal has been positively evaluated by all participating funding institutions, the researchers can then submit an application in the second step. This application must take into account all relevant national requirements. The last step follows the decision on whether to accept the application by the project manager or the government body. Only then can the joint partners apply for additional funding from the European Commission. This method is designed to stimulate collaboration and coordination and also emphasise the European dimension of the research proposal and the added value for the EU.

What goals is the German federal government following with this strategy?
Menzen: We want to use the Berlin Model to make the system for obtaining multinational funding for research projects as unbureaucratic and efficient as possible. This is essential because funding at a European level as part of the SET-Plan always takes place in close cooperation with the relevant national funding programmes and organisations.

Which projects could be implemented so far using the Berlin Model?
Menzen: A number of collaborations have been successfully established since 2012. This includes six binational joint projects on energy efficiency. These resulted from a joint funding announcement with Finland in 2013. In addition, collaborations exist with Austria and Switzerland in the research fields of energy efficient cities and hydrogen and fuel cell technology. We plan to further expand funding based on the Berlin Model in the future.

2-axis sun tracker from ZAE Bayern with its first functional models

Selected funded projects

Solar thermal heating and cooling systems for North and Central Europe

In a joint international project, the ZAE Bayern is developing components and systems for a solar thermal heating and cooling system together with its Finnish partners VTT, a technical research centre, and SavoSolar, a solar thermal collector manufacturer. These are specifically designed for use in Northern and Central Europe. The functionality and seasonal energy efficiency of the solution is being demonstrated by the scientists in a pilot plant in the Finnish town of Mikkeli.

The plant comprises a solar thermal flat-plate collector made of aluminium with transparent additional insulation and continuous heat flow transfer over its full surface, a multivariable thermally driven sorption cooling system with a heat pump module that uses the natural coolant properties of water and an improved low loss heat storage system.

The aim is to further optimise the efficiency and cost-effectiveness of the components. In addition, the scientists want to increase the proportion of solar power used for air conditioning in buildings and service water preparation through the seasons and minimise the total electricity consumption of the overall system. In parallel, the researchers are investigating the feasibility of integrating the thermal use of biomass to drive the sorption process in a laboratory experiment.

Functional models of the collector and the sorption cooling plant will be formed based on the preliminary experiments. The models will then subsequently be integrated into the pilot plant. It will be possible to estimate the overall potential of the energy system based on the Component Test System Simulation (CTSS) method and the operating results. The BMWi has provided the German part of the research project with 718,418 euros of funding. The project runs until October 2016 and is incorporated into a large German-Finnish cooperation with a total of four projects as part of the European Strategic Energy Technology Plan (SET-Plan) of the European Union. ■

Important links

www.bmwi.de
Federal Ministry for Economic Affairs and Energy

www.bmel.de
Federal Ministry of Food and Agriculture

www.bmub.bund.de
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

www.bmbf.de
Federal Ministry of Education and Research

www.bmwi.de/go/energieforschung
Energy research of the BMWi

www.ptj.de/angewandte-energieforschung
Energy Department at Project Management Jülich

www.forschungsjahrbuch.erneuerbare-energien.de
Database of all of the projects funded by the BMWi in the area of renewable energies

www.foerderinfo.bund.de
The German federal government's research and innovation funding advisory service

www.foerderdatenbank.de
Federal database with information on research programmes from federal agencies, federal states and the European Union

www.foerderkatalog.de
Federal database with information on projects funded by the federal government

www.forschungsnetzwerk-energie.de
BMWi research network for energy in buildings and districts

www.forschung-energiespeicher.info
Energy Storage Funding Initiative of the BMWi and BMBF

www.forschung-stromnetze.info
Future-proof Power Grids Funding Initiative of the BMWi and BMBF

www.eneff-stadt.info
EnEff:Stadt and EnEff:Wärme funding programmes of the BMWi - Research for Energy Efficiency

www.eneff-industrie.info
EnEff:Industrie funding programme of the BMWi – Research for Energy Efficient Industry

www.enob.info
EnOB funding programme of the BMWi – Research on Energy-Optimised Construction

www.kraftwerkforschung.info
Power plant and CCS technologies funding programme of the BMWi – Research for a New Generation of Power Plants

www.rave-offshore.de
Research at alpha ventus (RAVE)

www.dsttp.org
German Solar Thermal Technology Platform

www.bine.info
BINE Information Service on energy efficiency and renewable energies

www.horizont2020.de
Framework programme for research and innovation from the EU

www.windplatform.eu
European Wind Initiative (EWI)

www.eupvplatform.org
Solar Electricity Industrial Initiative (SEII)

www.solar-era.net
SOLAR-ERA.NET as part of the Solar Electricity Industrial Initiative

www.geothermaleranet.is
Geothermal ERA-NET

www.iea.org
International Energy Agency (IEA)

Statistical overview

Funding themes	Outflow of funds in million euros				Number of ongoing projects in			
	2011	2012	2013	2014	2011	2012	2013	2014
Wind energy	44.01	38.42	52.57	53.06	162	209	216	242
Photovoltaics	38.83	51.46	48.73	43.34	204	239	241	260
Solar thermal power plants	6.06	7.45	8.41	9.25	53	69	70	77
Deep geothermal energy	11.60	20.82	17.10	15.55	90	113	123	106
Hydropower & marine energy	0.49	0.98	1.25	1.21	5	8	9	15
Power plant technology and CCS technologies	21.22	23.00	27.82	26.74	183	208	214	233
Fuel cells and hydrogen	21.37	18.77	23.80	24.12	92	118	118	112
Storage	24.77	20.82	39.93	39.78	87	151	216	240
Grids	16.05	13.68	30.46	33.62	85	145	207	285
Energy efficiency in buildings and cities	31.14	42.17	52.28	55.19	313	362	398	412
Energy efficiency in the industry, commerce, trade and services sector	29.28	30.01	36.38	32.94	224	255	258	274
Overarching issues and systems analysis	7.67	8.60	11.70	10.82	83	86	90	92
Total	**252.49**	**276.16**	**350.41**	**345.61**	**1581**	**1963**	**2160**	**2348**

Funding themes	Newly approved projects in million euros				Number of newly approved projects in			
	2011	2012	2013	2014	2011	2012	2013	2014
Wind energy	81.21	78.31	36.75	38.51	68	75	56	63
Photovoltaics	66.43	65.43	33.99	66.91	90	80	35	90
Solar thermal power plants	8.89	18.02	8.65	7.44	16	25	14	22
Deep geothermal energy	21.44	17.43	19.21	12.65	37	29	25	15
Hydropower & marine energy	0.23	3.61	0.71	2.02	1	6	2	6
Power plant technology and CCS technologies	26.47	30.76	27.82	23.79	44	67	64	55
Fuel cells and hydrogen	20.41	32.65	22.85	21.50	36	33	27	28
Storage	10.97	88.02	49.29	35.39	16	101	71	57
Grids	25.88	46.32	43.04	71.03	25	78	73	152
Energy efficiency in buildings and cities	56.74	62.38	49.48	47.19	93	112	88	98
Energy efficiency in the industry, commerce, trade and services sector	36.55	40.56	33.84	38.60	60	71	49	83
Overarching issues and systems analysis	6.79	20.79	12.17	8.15	22	30	32	26
Total	**362.01**	**504.28**	**337.79**	**373.18**	**508**	**707**	**536**	**695**