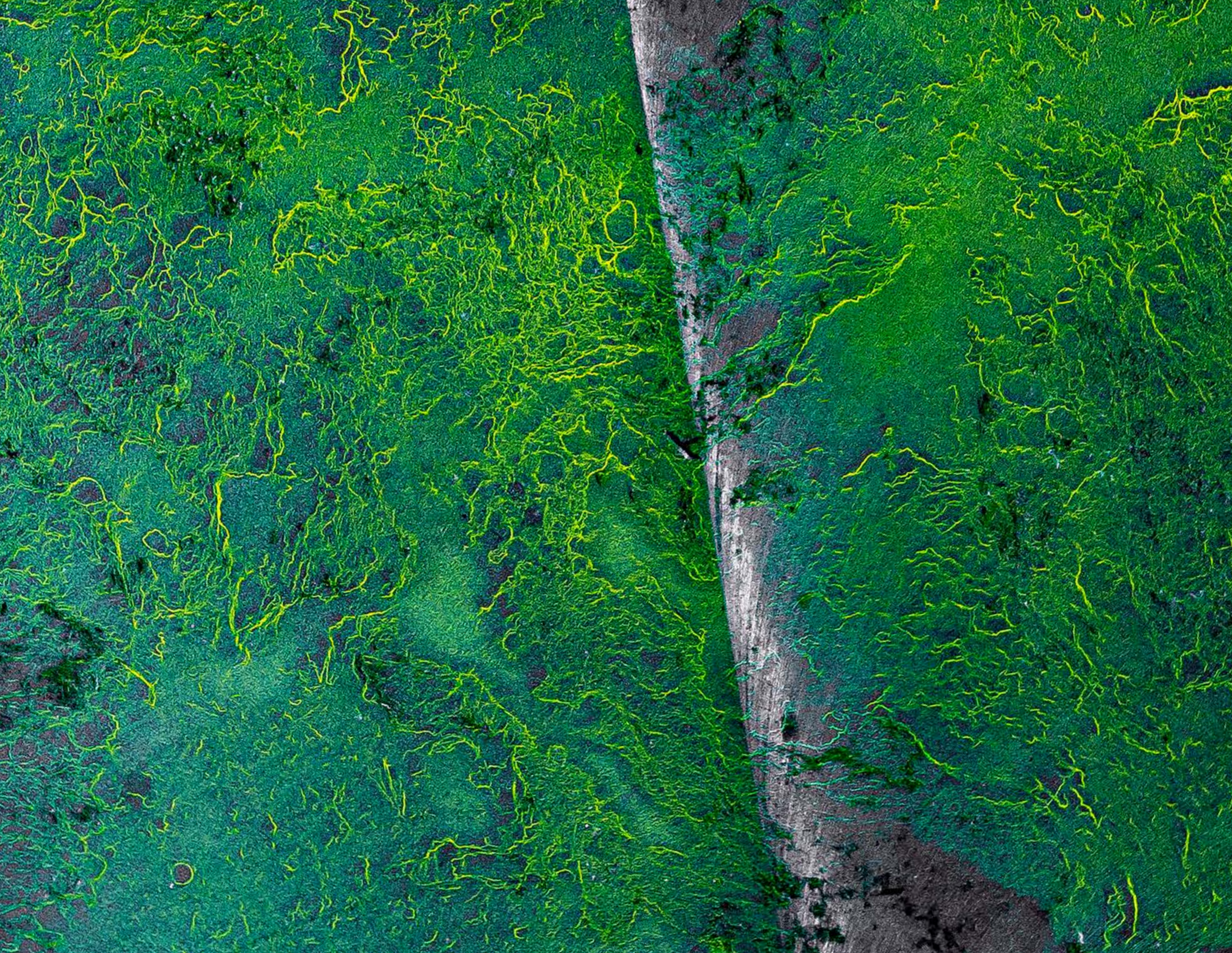
Federal Ministry
for Economic Affairs
and Energy

Energiewende
Switch to the Future

Report of the Federal Government on Energy Research 2017

Research Funding for the Energy Transition



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1. Research funding for the energy transition

Innovations prepare the path for tomorrow's world. They are an indispensable element precisely for the energy transition in the sectors of power, heat and transport. Energy efficiency is to be substantially increased by the year 2050 and at least 80 percent of the remaining energy demand covered by renewable sources. The foundation for this is provided by excellent research and development.

In Germany, almost one third of power is now generated by wind, solar, water or bioenergy plants, making renewable energies the most important source of power. At the same time, primary energy consumption has dropped noticeably in recent years and by 8.3 percent in the period between 2008 and 2014. A large number of research and development activities of committed universities, higher education establishments, research institutes and businesses have provided the foundation for this success. The Federal Government supports these endeavours with extensive funding measures because without further innovation it will hardly be possible to achieve the long-term objectives of energy and climate policy. The 6th Energy Research Programme now provides the basis for this. Over 17,300 projects have been funded by the Federal Government during the past 40 years, starting with the 1st Energy Research Programme in 1977.

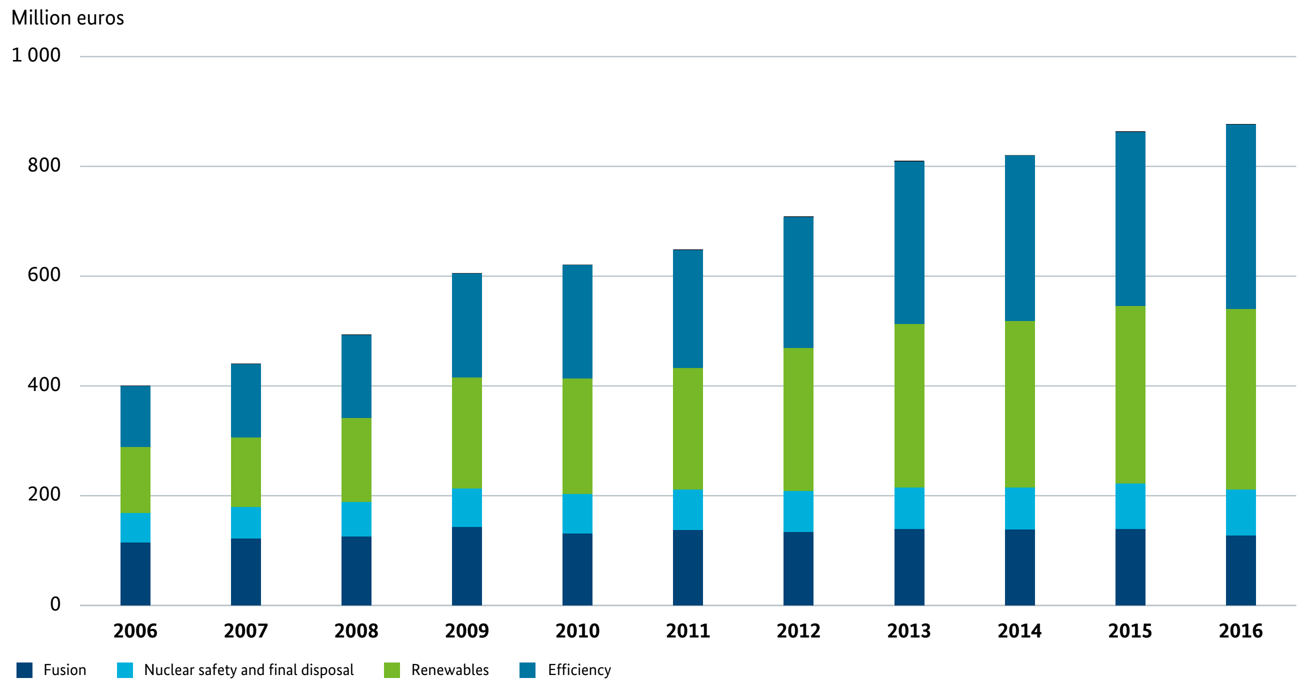
1.1 The Energy Research Programme of the Federal Government

The 6th Energy Research Programme provides the foundation for the funding of research, development and demonstration in the energy sector. The Programme was adopted by the Cabinet in 2011. It is an important element of the Federal Government's energy policy and is aligned with the objectives of the energy transition. The comprehensive project funding supports numerous activities of top level research in Germany in the area of renewable energies and energy efficiency.

1.1.1 Objectives and successes

The Federal Government's Energy Research Programme is an important contribution to the conversion of the energy system in order to secure a reliable and competitive supply of power and heat with sustainable mobility based on renewable energies. The Federal Government pursues a long-term funding policy here which is at the same time sufficiently dynamic and flexible to permit innovative, environmentally friendly and affordable applications, products and concepts to be generated. The energy transition will therefore

Figure 1: Overview of the topics in the Federal Energy Research Programme
(See data in Table 1)



become a successful brand "Made in Germany" throughout the world. The Federal Government implements the guidelines for funding modern energy technologies, innovative efficiency solutions and optimised systems using funding announcements and calls for proposals in the Energy Research Programme.

1.1.2 Participating departments

The Federal Ministry for Economic Affairs and Energy (BMWi), as the leading department within the Federal Government, is responsible for the coordination, programmatic orientation and further development of the Energy Research Programme. At the end of 2016, the BMWi launched the process of consultation in preparation for the 7th Energy Research Programme in order to systematically adjust the funding policy to the objectives and requirements of the energy transition and consolidate and expand on the progress already achieved.

The Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Food and Agriculture (BMEL) are also involved in implementing the Programme. The research funding from the departments covers the entire innovation chain, from basic research into energy technology through to applications-oriented research, development and demonstration as well as social aspects. In this way, project funding supports the transfer of promising approaches into competitive, affordable, environmentally friendly and reliable future solutions for the energy transition.

The BMBF is responsible for the project-oriented basic research in the areas of energy efficiency, renewable energies, nuclear safety, waste disposal, radiation research and fusion. The BMWi takes responsibility for applications-oriented research, development and demonstration for the entire spectrum of the energy system, from generation by renewable and conventional power plants, through transport, distribution and storage of energy through to a highly efficient use of energy in different sectors. The BMWi is also responsible for the funding of projects in nuclear safety research. The BMEL provides funding for bioenergy research projects.

This is supplemented by the institutional funding of the Helmholtz Association of German Research Centres (HGF) and of the Fraunhofer Society, the Max Planck Society and the Leibniz Association, which fall within the competence of the BMBF. The BMWi is responsible for the institutional funding of the German Aerospace Centre (DLR).

1.1.3 Development of funding

Research and development are central elements in the long-term success of the energy transition. This is why the Federal Government has further extended its commitment and has purposefully continued the positive trend of funding growth of previous years into 2016. All in all, some 875.98 million euros of government funding were used for energy research in 2016 (see overview in Figure 1). 862.73 million euros were expended in 2015. The thematic focus of research and development funding was placed on renewable energies and energy efficiency with a share of some three quarters of funds.

All in all, the Federal Government has invested around 12 billion euros[1] in the funding of non-nuclear energy research since the start of project funding with its 1st Energy Research Programme in 1977, thereby sustainably strengthening Germany as an industrial location, creating qualified jobs, enhancing competitiveness and increasing the export opportunities for German businesses.

The project funding figures in this report are also presented transparently in EnArgus (www.enargus.de), the BMWi's central energy research information system.

1.1.4 Evaluation and success monitoring

The efficacy of funding top level research is demonstrated by the successful transfer of results into practical applications. However, in addition to visible marketable applications and products or implemented concepts, scientific/technical evaluations are also a valuable instrument to assess funding measures and make recommendations on future activities. Evaluations and success monitoring also support the transparency of the Federal Government's research funding – an important objective of the 6th Energy Research Programme. Accordingly, the departments involved regularly conduct reviews of this nature to assess the efficiency and efficacy of the funding activities implemented.

1 Adjusted for inflation to around 15 billion euros (base year 2010)

In 2015, Project Management Jülich was commissioned with the conducting of concomitant success monitoring of the joint Energy Storage funding initiative of the BMWi and BMBF so as to be able to validly quantify the achievement of the objectives of this funding measure. Following a first interim report in June 2016, the final conclusions and recommendations will be available in spring 2017. However, the examination has already shown that the 186 million euros of funding provided have already stimulated relevant further developments of the basic materials research through to application-related demonstration. Impediments to a market launch could be reduced if not completely eliminated. Successes in the improvement of collaboration between the scientific community and industry in the area of energy storage – an important goal of the funding initiative – should be positively underlined here.

1.2 Structures of energy research policy

In addition to project funding, the Federal Government also pursues an intensive and transparent dialogue with energy research stakeholders so as to ensure the practical orientation of research and development activities and accelerate the transfer from laboratory into practice.

1.2.1 Energy Transition Research and Innovation Platform and Energy Research Network

The energy transition Research and Innovation Platform (FuI platform for short) is one of five of the BMWi's energy transition platforms and acts as a strategic advisory group on overarching issues of energy research policy. The platform provides the foundation for an intensive process of dialogue and participation between all stakeholders in the innovation chain. As an advisory group with stakeholders from politics, industry and science, the platform is part of the consultation process on the strategic alignment of energy research. In this way, the diverse research activities in Germany are to be strengthened and networked in order to make the further development and rapid introduction to market of new energy technologies and innovative procedures even more efficient. The plenary session of the FuI platform therefore brings all relevant interest groups together, including representatives from associations, researching businesses, research institutes and the government departments involved at a national and regional level. The plenary session takes place twice a year and discusses current developments from the energy research networks and the main results from adhoc working groups.

The FuI platform is founded on the seven energy research networks. They are open, theme-oriented and organised by the research stakeholders themselves. Two new elements were added in 2016, namely the Renewable Energies Research Network and the Energy in Industry and Commerce Research Network. The Energy in Buildings and Cities Research Network, the Power Grids Research Network, the Energy System Analysis Research Network, the Use of Bioenergy for Energy Research Network and the Flexible Energy Conversion Research Network, which is a further development of the former COORETEC research initiative, should also be mentioned here. All in all, more than 2,000 stakeholders are involved in the energy research networks and discuss joint challenges, trends and developments in their thematic areas. Collaboration in the networks takes place within working groups and regular conferences.

The energy transition Research and Innovation Platform and the energy research networks assume an important role as advisory groups within the consultation process of the 7th Energy Research Programme.

1.2.2 Energy Transition Research Forum

Key issues to be addressed and research requirements must be collected, assessed and prepared for the implementation of the energy transition. This is the task of the Energy Transition Research Forum. With the involvement of all departments, the BMBF brings together high-ranking stakeholders from politics, science, industry and the civil society in the Energy Transition Research Forum. Together they discuss and assess the science-based action options which the Energy Systems of the Future academy project (see Chapter 1.2.3) has prepared.

The central results of the work of the Energy Transition Research Forum are four Copernicus projects in which key issues of the energy transition are currently prepared. The projects are an important research initiative for the implementation of the energy transition (see Chapter 2.3.5).

1.2.3 Energy Systems of the Future Academy Project

The Energy Systems of the Future academy project is conducted jointly by the German scientific academies. The scientific expertise in Germany on energy issues is concentrated here on an interdisciplinary basis. In interdisciplinary working groups, more than 100 experts prepare action options for the conversion of the energy supply in Germany.

In addition to issues of principle viability of technologies to provide, transport and store energy, consideration is also given to economic, ecological, legal and social aspects. A systematic approach is adopted here which also looks beyond German borders.

The results obtained so far cover ten publications on urgent challenges of the energy transition, including flexibilisation concepts as well as raw materials for the energy supply of the future. The scientific contributions have been debated in the Energy Transition Research Forum, providing the foundation for the preparation of solutions on the transformation of the energy system.

New subjects, such as consumer policy, networking of power, heat and transport (sector coupling), distribution effects in the energy transition and energy union have already been initiated.

The academies conduct annual events on current issues and present their results to the public. The motto in 2016 asked how the joint venture could succeed. Over 150 stakeholders took part.

1.2.4 Central information system on energy research

Transparency is an important goal of the 6th Energy Research Programme and a significant cornerstone of energy research policy. The central information system EnArgus (www.enargus.de) provides a comprehensive insight into the diverse project-specific energy research activities of the Federal Government since 1977. The system contains more than 24,000 funded research projects in energy research, providing a detailed overview of the Government's activities since the start of targeted funding in the energy research programmes. In addition to the individual projects, a wiki provides information on the different energy topics, technologies and specialised terms.

The web-based portal is divided into two levels. One level provides the publicly accessible website for interested users with an insight into the funding policy guidelines, the different energy and efficient technologies and the funding projects. On the second level, EnArgus provides politicians, authorities and project partners with an in-depth, uniform and central access to the energy research landscape in Germany.

1.3 European and international networking

International cooperation is an important element for successful innovations from research and development, which is why the Federal Government advocates an international exchange at a European and global level. During the 2016 G7 Summit in Japan, participating states once again endorsed the significance of energy research in the mastering of global challenges presented by the transformation of energy systems and securing an affordable supply (G7 Ise-Shima Leaders' Declaration). The Federal Government underlines its conviction by its multi-faceted international commitment. Cooperation predominantly takes place within the European Union (EU) and the International Energy Agency (IEA) as well as via individual bilateral and multilateral initiatives.

1.3.1 European collaboration

The foundation for the funding of research and development within the European Union is provided by Horizon 2020, the European Framework Programme for Research and Innovation, (see Chapter 4.3). The aim is to promote scientific excellence, expand the leading role of industry and to support the mastering of major social challenges, also including the subject of secure, clean and efficient energy. Horizon 2020 provides for an overall budget of around 80 billion euros for non-nuclear energy research over the term of the programme from 2014 to 2020. Of this figure, some 6 billion euros are intended for the social challenge of secure, clean and efficient energy. Applicants can apply for funding through annual calls from the European Commission. A particularly high funding volume of some 350 million euros was earmarked in 2016 for the area of competitive, low-carbon energy technologies.

The Federal Government funds a network of so-called National Contact Points (NCS) which advise applicants on the funding opportunities and on the application requirements for Horizon 2020 funding. For the energy sector, the Energy Contact Point works on instruction of the BMWi and is located at Forschungszentrum Jülich.

Research, development and demonstration in the energy sector is based on the EU's Strategic Energy Technology Plan (SET Plan), which defines content-related priorities for the funding of innovations in the area of energy from the point of view of the member states. The SET Plan supports the transition to a competitive, low-carbon and secure energy supply in Europe and creates the foundation for intensive cooperation between the member states, businesses, research institutions and the EU.

The European Commission and the EU member states make use inter alia of the European Technology and Innovation Platforms (ETIP) such as Smart Networks for Energy Transition, Zero Emissions Platform or the ETIP Wind and ETIP Photovoltaics. The Federal Government also pursues the Berlin model in which bilateral and multilateral research projects are jointly funded in agreement with the member states concerned. Scientists are given support via national funding instruments by an institution in their own country.

The BMWi also funds synergies between national and European funding within Horizon 2020 through the support of the European Hydrogen and Fuel Cell Joint Undertaking – FCH2 JU – and the European Technology and Innovation Platforms (ETIP). The BMWi also participates in ERA Net Cofunds such as the Solar-ERA.Net, Geothermal ERA or Accelerating CCS Technologies (ACT).

One example of bilateral European cooperation is the second German-Greek Research and Innovation Programme published by the BMBF in December 2016. Its focal areas are energy research, human and social sciences, materials research, optical technologies, bioeconomics and health research. German and Greek industrial partners as well as young scientists from both countries cooperate in the project. This ensures the transfer of knowledge and technology and creates the foundation for the long-term development of skills. The BMBF and the Greek Ministry for Education, Research and Religious Affairs have earmarked a total of 18 million euros for the programme. Both countries are intensifying their research and innovation cooperation noticeably because the funding to intensify cooperation with Greece which started in 2013 has led to over 20 successful bilateral research projects. The RES-DEGREE project is to be stressed here, which conducted a long-term scenario analysis for the power systems of both countries and the assessment of the results in terms of the challenges and problems of the extensive integration of renewable energies.

1.3.2 International collaboration

Intensive cooperation is taking place not only at a European but also at an international level in the area of energy research between governments, research institutes, universities and industrial undertakings. The most important platform for worldwide cooperation in this sector is the International Energy Agency (IEA). However, there are also a number of bilateral and multilateral cooperations here.

International Energy Agency (IEA)

As an independent multilateral entity within the Organisation for Economic Cooperation and Development (OECD), the IEA pursues the goal of a secure, affordable and environmentally friendly energy supply in the 29 member states and beyond. New synergies and stimuli for the energy transition in Germany and joint solution approaches to worldwide challenges result from this form of international cooperation.

Cooperation in energy research is of special importance and takes place in the technology network of the IEA, comprising of working parties and so-called Technology Collaboration Programmes (TCP). The technology network involves some 6,000 experts across the globe and addresses a broad spectrum of energy technologies. Experts from Germany are involved in all four working parties and in 24 of the total TCPs currently in operation. In addition, important energy-technology questions are discussed in the Committee on Energy Research and Technology (CERT) in which the IEA member states are represented. Publications of the IEA such as the Energy Technology Perspectives or Technology Roadmaps are also discussed in the CERT in particular. The BMWi represents the Federal Government in the CERT.

Mission Innovation

Mission Innovation is a large scale international initiative to promote research and innovation on clean energy technologies and was brought to life during the Climate Conference COP21 in Paris in November 2015. Mission Innovation is a group of 22 states, including the USA, China, India, Brazil, UK, Japan, France and Germany as well as the European Union. As part of the initiative the countries involved wish to double their expenditure on research and innovation in the energy sector within five years and intensify international collaboration. There is also an intensive exchange of information to promote transparency, collaboration and the dissemination of results. Private investors are also to be encouraged to invest in research and development of clean energy technologies. One example is the Breakthrough Energy Coalition, which was similarly brought to life during the COP21 headed by Bill Gates.

Seven innovation challenges of particular importance for the member states were identified and presented during the COP22 in Marrakech. The work in Mission Innovation is geared to these innovation challenges.

The BMWi, BMBF and BMEL are responsible for implementing Mission Innovation within their respective departments in the 6th Energy Research Programme. The Federal Government's involvement in Mission Innovation underlines the high importance attributed to research and development for clean energy technologies and therefore the will to further advance the considerable work already being conducted to promote innovation.

Bilateral initiatives

The BMBF has funded the bilateral German-Canadian Co-operation on Kinetics and mass transport Optimization in PEM fuel cells (GECKO) which is designed to optimise components in low-temperature PEM fuel cells for mobile applications. The German and Canadian research partners are leading institutions throughout the world in the area of fuel cell technology. An important result showcased in the f-cell awards was the development of a simplified manufacturing method for the membrane electrode unit, one of the key components in fuel cells. The successful research work and the close scientific cooperation established with the Canadian partners will be continued beyond 2016 in the new joint project on German-Canadian Fuel Cell Cooperation: Diagnosis and Development of Components for Automotive Fuel Cells project (DEKADE). The aim is to develop innovative catalyst systems, electrodes and membrane electrode units which function with only a small amount of platinum and which are therefore more favourably priced. They are also to be simpler to produce whilst at the same time satisfying the requisite performance parameters and resistance to age.

In its China strategy, the BMBF has opened up paths of strategic partnership of both countries in the area of research and innovation. So-called 2+2 projects are funded in the energy research sector, where the involvement of at least one German and one Chinese research institute and at least one German small or medium-size enterprise (SME) and one Chinese research industrial partner is envisaged.

Germany meets its international responsibility in the mastering of global challenges through cooperation with emerging and developing countries in research and development. The BMBF CLIENT II – International Partnerships for Sustainable Innovations funding measure therefore stands for the funding of demand-oriented research and development cooperations with partners in selected emerging and developing countries. Priority project topics include climate protection/energy efficiency and sustainable energy systems.

1.4 National networking

Close networking of the stakeholders at a political, scientific, entrepreneurial and social level is necessary for the broad field of energy research. The Federal Government coordinates this networking using the Energy Research Policy Coordination Platform led by the BMWi. It serves the interdepartmental exchange of information and the agreement and coordination with other funding programmes with close references to energy research.

With total funding of some 267 million euros in 2015, the 16 federal states have made an important contribution to research funding for the energy transition (see Chapter 4.2). The Government-Federal State Dialogue on Energy Research Policy takes place annually under the lead of the BMWi to guarantee close coordination of the focal areas, subjects and trends. Focus is currently placed on the involvement of the federal states in the preparation of the new Energy Research Programme.

2. Project funding in the 6th Energy Research Programme

2.1 Energy conversion

2.1.1 Photovoltaics

More and more countries around the world are increasing their use of solar energy. In 2016, global installed voltaics (PV) capacities rose to a record level of 295 gigawatts. For German machine and component manufacturers, this market trend is reflected in full order books. Even if the new installed capacity of just under 1.5 gigawatts in Germany lags distinctly behind the planned increase, in the autumn of 2016 the Mechanical Engineering Industry Association (VDMA) reported that the manufacturers of PV production equipment were recording a continuous rise in new orders and sales compared to the previous year. Technical components "Made in Germany" are in demand throughout the world. According to the Association, over 90 percent of production now goes abroad. By contrast, there are only a few companies in Germany producing solar modules and cells, not least due to the cheaper Asian competitors.

Increasingly more efficient modules on the basis of crystalline silicon are establishing themselves on the PV market. Currently, the p-PERC technology (passivated emitter rear contact on p-type wafer substrates) are popular, in particular, which can be integrated very well into existing production lines. The heterojunction technology is viewed to be a possible next step towards more efficient modules in which a border layer of two different semi-conductor materials can be cleverly used.

In the area of thin-film modules on the basis of a chalcopyrite semi-conductor (CIGS), industry and research are working hand in hand to make use of the advantage of this technology, particularly for photovoltaics integrated in buildings.

The thin-film systems of organic photovoltaics (OPV) are on the threshold to industrial production whilst the promising perovskite-based photovoltaics are still at the basic research stage.

Government research funding by the BMWi is focussed on reducing material and energy consumption, establishing more effective production processes and increasing the degree of efficacy of the cells and modules in order to further cut costs. The BMWi also funds research activities for photovoltaics integrated in buildings, recycling and issues of quality assurance.

New research approaches are investigating tandem solar cells in search of even higher module performance. In the long term, degrees of efficiency of over 35 percent are possible here. Research institutions and industrial companies are therefore working intensively in different projects to develop a tandem generation of solar cells with a bottom solar cell on the basis of crystalline silicon which builds on established technologies. In the PersiST project of the Fraunhofer Institute for Solar Energy Systems (ISE) scientists are working on a perovskite silicon tandem solar cell with a degree of efficiency of over 29 percent. The researchers are examining how the perovskite and silicon solar cells can be ideally combined by adjusted contact and charge carrier transport layers. It is to be possible to realise the tandem solar cell on an area of 100 cm^2.

In addition to progress in efficiency through optimised solar cells and modules or intelligent and more compact inverters, research is also increasingly concentrating on the means and workflows of production for the photovoltaic modules and cells. In order to achieve further cost savings here and to remain internationally competitive, the systems manufacturers are pursuing innovative production processes within the Industrie 4.0 framework. The aim is to link up industrial production and the information and communication technology more closely so as to reduce costs with the assistance of self-optimising production plants.

Research funding makes a decisive contribution to generating trendsetting expertise in industrial companies, research institutes and universities. As a result of the successful transfer of innovation to industry, German photovoltaics system manufacturers and component suppliers are faring well in international competition. The BMWi initiated the Renewable Energies Research Network in 2016 to ensure the sustainability of this success.

In order to fully exploit the location advantages from research and development, the Research and Development for Photovoltaics initiative was implemented by BMWi and BMBF back in 2014. In February 2016, a status seminar took place on this initiative during which the successes which had so far been achieved were presented. In summary, production-related innovations in module technology and plant construction as well as complex system-related approaches are the focal areas of the initiative.

Some 63.99 million euros went to current projects in the funding priority of photovoltaics. Funding was distinctly increased compared to the previous year. Whilst a total of 99 new projects with a total volume of 80.59 million euros were approved in 2015, 166 new research projects with a total volume of 116.57 million euros were approved in 2016 (see Figure 2).

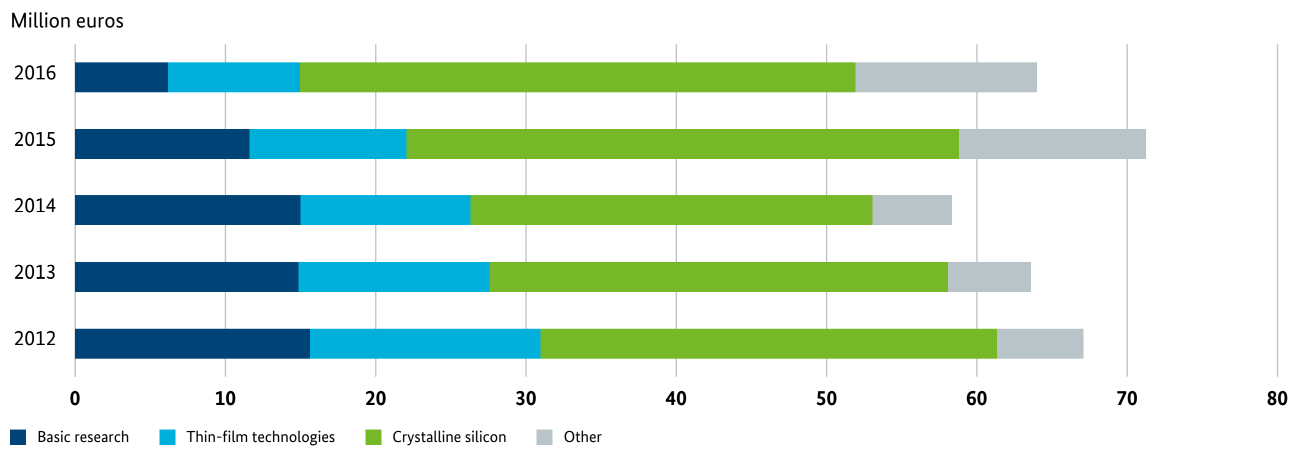
Back in 2010, the Photovoltaics Innovation Alliance was set up by BMBF and BMWi with a funding volume of 100 million euros aimed at extending the innovation lead of the German solar industry by way of research and development work. One basic research highlight is the SISSY project on the use of synchrotron radiation for the further development of thin-film solar cells. The BNBF funds the globally unique Labor Energy Materials In-Situ Laboratory Berlin (EMIL) at the Berlin synchrotron source BESSY II at the Helmholtz Centre Berlin for Materials and Energy. EMIL was opened at the end of October 2016 and handed over to researchers.

As part of the BMBF Materials Research for the Energy Transition call for proposals, five projects have now been set up, focussing on the development of perovskite solar cells. Three of the projects address the basic understanding of the perovskite solar cells and their improvement. In a further project, the world record CIGS cells of the Centre for Solar Energy and Hydrogen Research in Stuttgart are to be combined with perovskite cells to produce tandem cells with very high degrees of efficiency. A new group of young researchers, which has set itself the goal of moving into the efficiency range of 30 percent with the assistance of silicon perovskite tandem solar cells, took up work at the Helmholtz Centre Berlin for Materials and Energy in the summer of 2016. During a BMBF workshop in Würzburg in October 2016, the German perovskite researchers met internationally esteemed colleagues in order to present and discuss the latest results of perovskite research. It has been possible to catch up with the world leaders in perovskite research using the BMBF funding.

Measures outside the Energy Research Programme

Scientists from research institutes and industry are working together on developing innovations and cost-cutting procedures in the still young field of organic electronics in the BMBF funding initiative entitled Organic Electronics, in particular Organic Light Emitting Diodes and Organic Photovoltaics. One area of interest is to increase the efficiency of organic solar cells and modules so as to make them attractive for the photovoltaics market. The now completed MEDOS project permitted the full analysis and explanation of the correlation between molecular properties, structure and component characteristics of solar cells, leading to the manufacture of more efficient solar cells.

Figure 2: Funding for photovoltaics
(See data in Table 2)



2.1.2 Wind power

Wind power currently accounts for the greatest share in power generated from renewable energies in Germany. At many locations it is the most favourably priced technology in the field of renewable energies and therefore a central element of the energy transition. The trend both on land and at sea is continuing towards ever more powerful plants and the connection of weak wind locations.

Over the past 20 years, the wind industry has made great progress, reducing power generation costs by 60 percent through research and development work. The costs are now between 5.3 and 9.6 cents per kilowatt hour for onshore wind power plants in Germany. The onshore wind power has already reached a high level of technical development but power generation costs must be reduced still further. In recent years, ever larger and therefore more powerful systems have therefore been built. In order to bring in the ideal "wind harvest", this has been accompanied by increasingly higher towers and longer blades. The average blade diameter onshore is now between 120 and 130 metres.

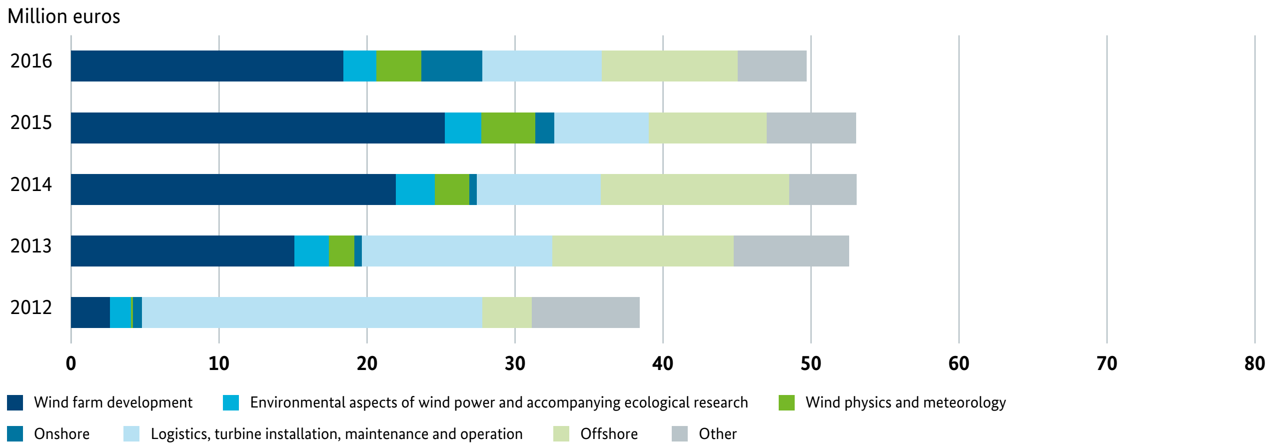
In the offshore area, the power generation costs are currently around double the costs for onshore. In an effort to reduce the costs, scientists at universities and research institutes and experts in industry are conducting research on further innovative technical solutions. One research focus is placed on the interaction between the individual wind power plants of a wind park on the one hand and between different wind parks on the other. The loads on the systems can therefore be reduced and a longer lifecycle and less damage achieved in this way. Research and development work conducted in recent years is also responsible for the fact that suitable sound protection measures, such as the big bubble curtain or suction buckets, are on the market which considerably reduce noise and therefore contribute to the protection of marine species.

The BMWi's research funding continues to pursue the objective of increasing yield and reliability whilst cutting costs in the area of wind power. Technical innovations and strategies will be necessary here also in years to come. Larger and higher wind power turbines are creating new challenges for research and development in view the high weight and the growing mechanical loads. New materials and composite materials are called for in the same way as innovative construction concepts and drive trains which are adjusted to the higher masses and forces.

In 2016, the BMWi approved 93 new projects with a funding volume of 86.24 million euros in the area of wind power. Ongoing research projects have been funded with some 49.69 million euros (see Figure 3).

In order to reduce the loads on large blades, experts are conducting research into intelligent solutions in which, for example, the blades can adjust themselves to the local wind conditions through innovative components. Different versions are being tested in wind tunnels and outdoors in the SmartBlades2 research project. Under the coordination of the German Aerospace Centre (DLR), the project partners

Figure 3: Funding for wind power
(See data in Table 2)



wish to produce 20 metre long demonstration blades and further blade components and examine them in tests on test stands, wind tunnels and outdoors.

The production processes for blade manufacture must also be further optimised to reduce the costs. The blades of wind power turbines are currently still made by hand to a great extent. The Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) has therefore put a demonstration production centre into operation in Bremerhaven together with partners as part of the BladeMaker research project in which automation techniques are being developed and tested.

The BMWi is also funding outdoor wind power test fields. Three new test fields were approved in 2016. The German Research Facility for Wind Energy (DF Wind) in Lower Saxony is investigating on flat areas how wind power turbines can produce favourably priced electricity efficiently and with little noise. The Fraunhofer IWES North-West is also developing and looking after the Bremerhaven test field. The prototype of an 8 megawatt system is currently being installed here, which is connected with the IWES infrastructure on site. This will permit the results of the laboratory investigations to be systematically compared with the field measurements and the test procedures to be improved accordingly. The WINSENT collaborative project in south Germany investigates the challenges arising from the operation of wind power turbines in complex mountainous terrain.

The BMBF supports basic research in the area of wind power with a number of initiatives for the strategic networking of infrastructure measures, institutional funding and project funding, particularly in the Materials Research for the Energy Transition funding initiative. An important challenge continues to be increasing the lifecycle of wind power turbines.

One example is the White Etching Cracks joint project. The bearings of wind turbine gears are particularly affected by material failure through white etching cracks. This damage mechanism is one of the reasons for the failure and therefore increased costs of wind power. A group of young researchers at the Max Planck Institute for Iron Research is investigating this problem at the atomic level in the White Etching Cracks project. If the project proves successful, the industrial potential will be great because a new, cheap and more wear-resistant bearing steel for all bearing applications would be available.

A further example is the EISAB collaborative project in which the ice and frost formation on wind power turbines is examined. This reduces the degree of efficiency and represents a high safety risk. Headed by the Technical University of Dresden, an anti-ice coating is being developed on the basis of an active polymer system. The great significance of this topic was impressively shown by the great interest of the participants from the scientific and industrial world at the Ice-resistant Surfaces innovation exchange in September.

2.1.3 Bioenergy

The BMEL's contribution to energy research consists of funding measures for research, development and demonstration projects on the use of sustainable raw materials for energy purposes as an element of the Renewable Raw Materials funding programme. The funding programme also covers measures outside energy research such as growing and cultivation, use of biomass as a material, international cooperation and the social dialogue.

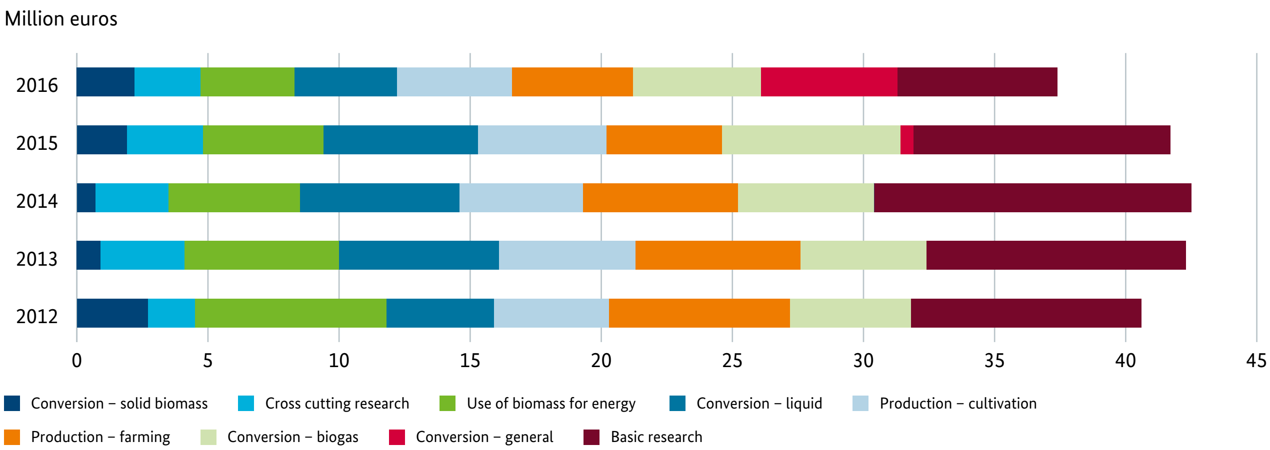
The Renewable Resources funding programme has been investigating the energy recovery from renewable raw materials and from residual and by-products of agriculture and forestry production since the year 2000. The currently applicable version of the funding programme was published by BMEL on 7 May 2015.

Two new priority areas on the basis of the Renewable Resources funding programme deal exclusively with the recovery of energy from biomass, with research being funded by the Energy and Climate Fund (EKF):

- Identification and development of technologies and systems for the generation and use of bioenergy with the objective of further improving carbon footprints in the main fields of use of electricity, heat and fuels
- Optimisation of the integration of bioenergy in regional and national energy (infrastructure) systems (heat, power, mobility) with the objective of improving system stability and energy efficiency.

In 2016, the funding for new projects in the BMEL portfolio was 24.45 million euros. During the course of 2016, 109 new projects were started whilst at the same time some 28.05 million euros were spent on 306 ongoing research projects (see Figure 4).

Figure 4: Funding for bioenergy
(See data in Table 2)



The BMWi supports research, development and demonstration projects on a technically, ecologically and economically optimised use of biomass for energy purposes that systematically makes use of the biogenic residual materials from waste as well as from agriculture and forestry production, increases degrees of efficiency or opens up new coupling or cascade use paths. Emphasis is placed on the generation of heat and electricity, combined power and heat, flexibilisation and the integration of bioenergetic applications into the entire system.

In 2016, the BMWi approved 37 new projects with a funding volume of some 5.98 million euros in the funding area of bioenergy. Some 3.66 million euros went to 100 ongoing research projects. The programme is accompanied by the DBFZ Deutsches Biomasseforschungszentrum gGmbH with the objective of networking and knowledge transfer.

One focal area of the BMBF's research funding is the provision of network services in order to make use of the high flexibility of bioenergy in the entire system. The principle of an innovative electro-biogas reactor was demonstrated for the first time in the world in the E S E – Biogas project as part of the BioProFi – Bioenergy – Process-oriented Research and Innovation funding initiative of the BMBF. It is considerably more resistant to process disturbances. Furthermore, an IT-based solution for real time control of biogas plants was developed in the Methanoquant and ELAST2P projects. It supports the flexible operation of biogas plants and therefore decisively improves the provision of compensatory energy in an energy system which is increasingly based on fluctuating energy suppliers.

A further area of focus of the BioProFi initiative is the generation of chemical energy suppliers and base chemicals for the chemical industry so as to be able to substitute the fossil starting materials here. A continuous high-pressure laboratory system has been set up in the AG-HiPreFer project for this purpose, enabling biomethane to be fed into existing remote gas lines without any additional high energy compaction. A new approach to hydrothermal biomass liquefaction has been developed in the FeBio@H2O project, permitting hydrocarbons to be generated from different biomasses. They can then be used in future as biofuels, for example, and therefore have the potential to significantly contribute to cutting carbon emissions.

In order to completely avoid competition with food production, industrial biomass production on algae base has also been further investigated. An integrated utilisation chain in sustainable aircraft fuel, lubricants and building materials was realised on the basis of algae and yeasts in the Advanced Biomass Value project. The OptimAL and Albira projects examined the fundamentals of generating biokerosene and chemical starting substances from algae.

2.1.4 Deep geothermal energy

Geothermal systems make use of the heat from the earth to produce electricity or to heat buildings or housing estates. The energy source is a stable factor in the renewable energy mix of the future because it is available independently of weather conditions. In addition to the production of heat for heating purposes, it can therefore contribute to covering the basic load and gaps in the power supply.

In recent years, much research and development work has been conducted in universities, research institutions and industry. This has amongst other things contributed to distinctly increasing the serviceable life and quality of pumps and other technical components. The collection and preparation of geological and other geothermically relevant data is supported in different research projects. The objective is to set up data pools which are as comprehensive as possible on the geothermal locations in Germany. On this basis, the exploration risk and therefore the connection costs can be reduced.

So as to be able to make greater use of the potential offered by geothermal energy, further research and development work must be done from the planning of systems, through exploration of the sites to the actual drilling and construction and final operation of geothermal energy systems. The BMWi pursues the strategy of reducing costs with the assistance of innovative approaches in all parts of the value added chain so as to make deep geothermal energy more economical in future. With its multi-year research funding, the BMWi provides reliable framework conditions to permit comprehensive research work.

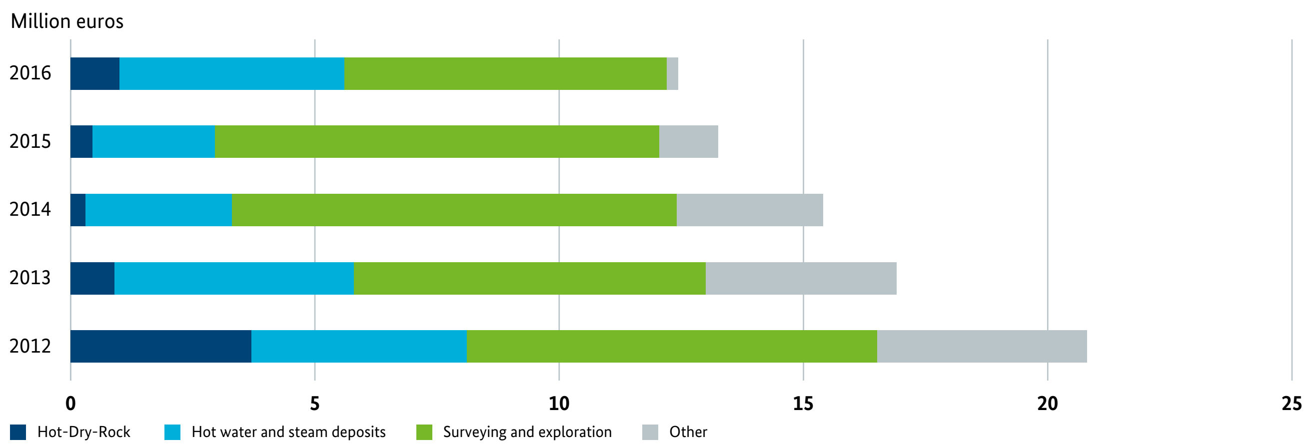
In 2016, the BMWi approved a total of 22 new projects with a funding volume of some 19.55 million euros for research activities in the area of geothermal energy. At the same time, around 12.54 million euros were spent on ongoing research projects (see Figure 5).

One focal area of BMWi research funding is to further develop exploration methods in the search for suitable locations. Since the costs for drilling are very high, the risk of not finding a suitable water reservoir or sufficiently hot rock must be minimised. For this purpose, innovative approaches to exploration will continue to be funded into the future and the existing geothermal information system GeoTIS further developed.

In the Dolomitkluft research project, 50 kilometres south of Munich, drill cores are now being taken from a depth of just under 5,000 meters for the first time. One of the aims of the scientists is to examine the influence of the high temperature and the enormous pressure at a depth of 5,000 meters on the porosity and permeability of the rock.

New findings on innovative materials or corrosion protection and on seismic measurement procedures or the monitoring of systems round off the research portfolio. Corrosion and mineral deposits disturb the operation of geothermal systems considerably. One of the reasons is the microbial infestation of surfaces in the systems. These biofilms are the focus of the BioKS collaborative project which is coordinated by the German Research Centre for Geosciences (GFZ) in Potsdam.

Figure 5: Funding for deep geothermal energy
(See data in Table 2)



2.1.5 Power plant technologies

Conventional power plants make an important contribution to securing the energy supply today and also in the medium term. However, new challenges arise in the context of the energy transition. Whereas the plants have so far been designed for long operating phases in so-called full-load operation, they must now react flexibly to compensate for the weather-dependent fluctuations in the production of power from wind and sun.

The altered tasks have an impact on the operation of conventional power plants. They must be adjusted for a cost and resource efficient partial load and minimum load operation. This also includes the use of different fuels and flexible combustion systems alongside fast start-up and shut-down speeds. These altered operating conditions place an unusual load on components and material because the existing plants have been designed for permanent operation with a constant load.

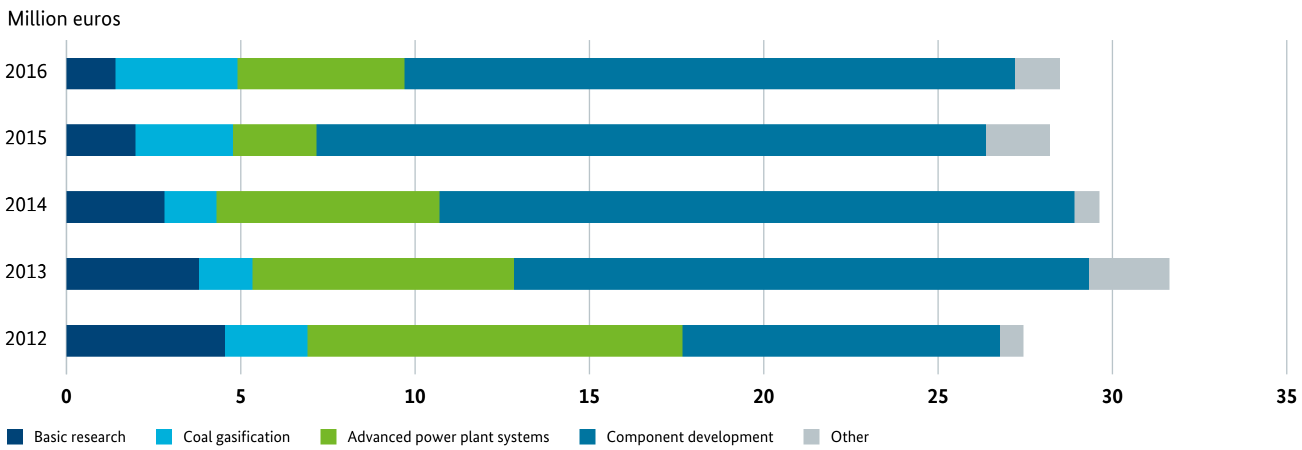
Technical innovations continue to be in demand in order to reduce carbon emissions, also including carbon separation technologies. The BMWi funds research projects which address these topics.

An important element in the realignment of the Government's funding policy in this area is the Flexible Energy Conversion Research Network which was established at the beginning of 2017 as a further development of the COORETEC initiative. New topics such as solar-thermal power plants, decentralised power generation and storage technologies will in future supplement the portfolio in the new research network. The members of the network therefore represent a broad research landscape and support the further development of the funding strategies with technical expertise.

In the area of conventional power plant technology and carbon separation, the BMWi approved a total of 73 new projects with a funding volume of 29.03 million euros in 2016. A total of 28.52 million euros were spent on ongoing projects (see Figure 6).

The BMWi's research funding is aimed at making power plant technology more efficient, cleaner and more flexible. Central areas of research are therefore focussed on investigating innovative materials as well as reducing carbon emissions. The aim of the MemKoR collaborative project is to reduce the release of carbon into the atmosphere. Using gas separation membranes at the end of the power plant process serves to selectively separate out the carbon which is then either stored or re-used. Developments of innovative simulation procedures are also funded, which contribute to demonstrating the altered operating conditions with a high share of renewable energies in flexible models. In the DYNSTART simulation research project, scientists examine how the required flexibility can be achieved in coal-driven power plants. The aim is to make a clear statement as to whether and how the power plants will be able technically and economically to operate at minimum loads of up to 12.5 percent.

Figure 6: Funding for power plant technologies
(See data in Table 2)



In the area of basic research on power plant technologies, the BMBF similarly supports the topic of flexibilisation as a bridge technology for the energy transition. Focus is placed on projects that examine the properties and behaviour of innovative materials under extreme conditions. Projects are therefore funded as part of the Materials Research for the Energy Transition initiative that, in addition to high-temperature-resistant steam producing materials, investigate new ceramic materials for use in gas turbines in particular. Attention is focussed here on increasing the degree of efficiency, achieving a load-flexible operation and using regenerative fuels in gas and steam turbine power plants as well as in microgas turbines which can be used decentrally. In addition to approaches for the manufacture of corresponding gas turbine components, the suitability of different ceramics and fibre composites are investigated. The BMBF funds two young researcher groups on these two topic complexes in the form of the FLEXIKON and MAXCOM projects. The FLEXIKON project conducted by the Federal Agency for Materials Research and Testing (BAM) examines the foundations for materials used in load-flexible conventional power plants. The MAXCOM project of Forschungszentrum Jülich examines innovative ceramics which permit an increase in the operating temperature in the gas turbines and therefore an increase in the degree of efficiency.

2.1.6 Fuel cells and hydrogen

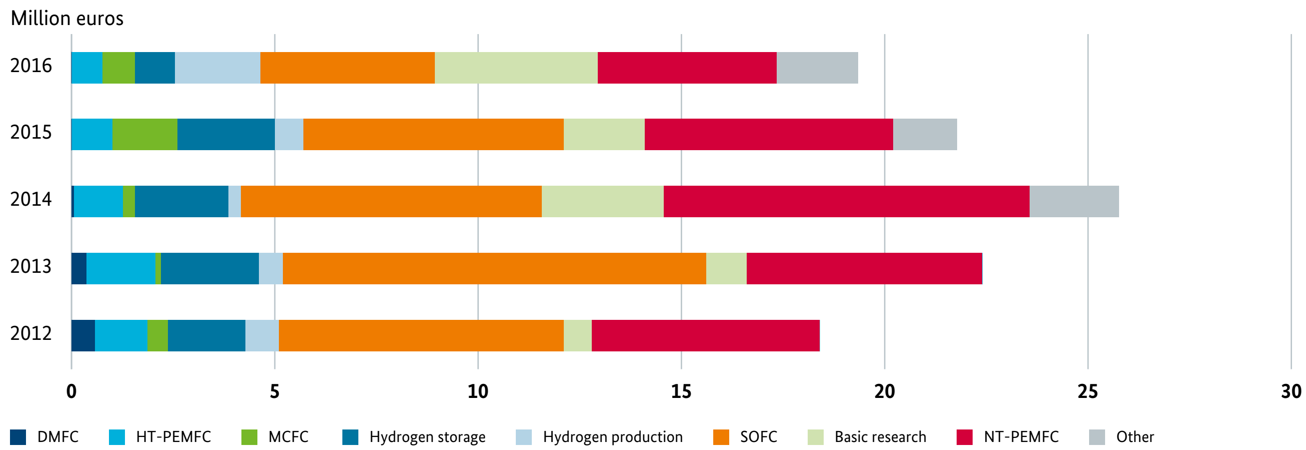
Fuel cells could play an important role in the future energy system because their efficient energy conversion offers many advantages in stationary and mobile energy supply. Compact, robust, durable, cost- and applications-efficient systems are the challenges of the future for research and development.

Through the efficient and low-pollutant use of a sustainable energy source such as hydrogen, fuel cells can in future supersede conventional energy convertors and reduce carbon emissions in transport and in stationary energy supply. Hydrogen is an important element of a sustainable energy economy in the transport sector and in the storage of regenerative energies. If wind power turbines produce more power than the grid can use, the opportunity exists, for example, to use the surplus energy for the electrolysis of water and to store the hydrogen generated or to feed it into the gas grid.

The technology therefore has key technology potential in the energy transition. The BMWi funds research and development of the next generation of fuel cells along all stations of the value-added chain which improve the level of maturity of the technology, thereby preparing the way for production in Germany.

The BMWi funding for fuel cells and hydrogen technologies is incorporated into the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP) which is continued after 2016 as state programme NIP2. The aim is to bring the technology to market maturity in the next ten years (2016 to 2025) in order to develop the industrial value added of the fuel cell and hydrogen technology in Germany at an internationally competitive level.

Figure 7: Funding for fuel cells and hydrogen
(See data in Table 2)



Energy research in the area of fuel cell and hydrogen technologies was funded in 2016 with some 19.69 million euros for 147 ongoing projects (see Figure 7). 28 new projects with a funding volume of 18.48 million euros were approved in 2016.

The objective pursued in the stationary use of fuel cells is to improve the serviceable life of fuel cells to distinctly beyond 20,000 operating hours in the direction of 60,000 hours, thereby offering a real alternative to applications in the building sector. Added to this is the development of favourably priced solutions both for core components – such as membrane electrode assemblies (MEA) - and in peripheral components (pumps, valves, sensors).

Fuel cells are also efficient automotive drives. They achieve a distinctly higher system degree of efficiency compared with combustion engines. To ensure that mobility with fuel cells reaches a significant share in Germany by 2050, scientists are developing and optimising suitable systems and components for mobile applications in different research projects. They must be durable and very efficient but at the same time very light and compact as well as tough and resistant to vibrations if they are to be economically competitive.

In basic research, the BMBF projects address technologies of the next generation with lower costs and higher serviceable lives as well as future technologies. They also include ceramic high temperature fuel cells which promise to be particularly efficient also in their inversion as electrolysers. Their areas of application range from domestic electricity and heat generation through grid-independent and onboard power generators to the power plant scale as well as the generation of gas and the use of carbon. The leading research institutes collaborate throughout Germany in the “SOFC-degradation” project in order to decisively improve the longevity of these energy converters.

Reducing the content of precious metals, in particular platinum, is an important step towards the economic use of fuel cells. The BMBF funds the development of highly efficient catalysts which are low in precious metals (reaction accelerators) and of innovative membranes as core components of fuel cells and electrolysers.

Hydrogen must be stored. BMBF-funded projects investigate the geological substrate for storage purposes and develop new materials for hydrogen drying and storage. For example, the RevAl and HySCORE collaborative projects pursue innovative approaches to binding hydrogen in solids and releasing it again so as to obtain efficient storage for mobile and stationary applications. In principle, hydrogen can also be directly generated from solar energy without taking the path through electrolysis systems. Projects examine the fission of water by means of sunlight in one step (photoelectrolysis) as a future topic. According to the DuaSol project, a process of this type could also be used in the cleaning of waste water.

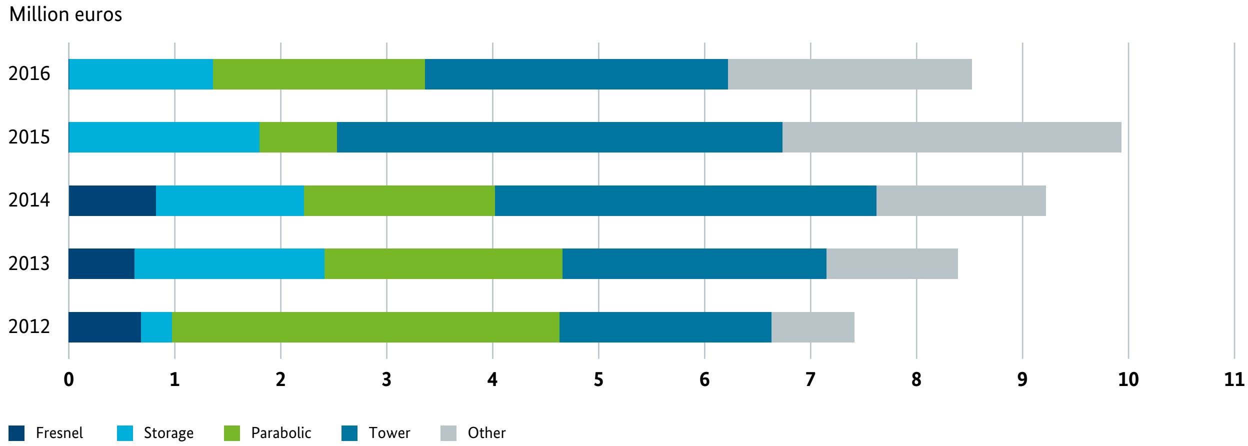
The BMBF has funded hydrogen and fuel cell technologies since 2013 above all in the Materials Research for the Energy Transition initiative and in a German-Canadian cooperation (GECKO/DEKADE, see Chapter 1.3.2). Hydrogen storage and electrolysis were also a subject in the inter-departmental Energy Storage funding initiative (see Chapter 2.3.2). Special requirements and new concepts for electrolysers as part of power-to-X technologies are the subject of the major projects P2X and Carbon2Chem (see Chapters 2.3.4 and 2.3.5). The HYPOS – Hydrogen Power & Storage Solutions East Germany syndicate is a major project on the subject of hydrogen.

2.1.7 Solar thermal power plants

Solar thermal power plants use the concentrated heat of the sun to drive turbines which supply entire cities with electricity. High direct solar radiation is required for this technology, as exists in southern Europe, Africa or in parts of South and North America. At the end of 2015, global capacity was already 4.8 gigawatts with a rising trend. Experts estimate that the power installed around the globe will triple or quadruple in the next ten years. Large solar thermal power plant projects are planned or under construction in places such as Morocco, Saudi Arabia, Dubai and South Africa.

The parabolic trough technology with thermal oil as heat transfer medium is the most widespread technology in solar thermal power plants. The high quality trough collectors reflect the direct radiation of the sun onto the receiver pipe through which the heat transfer medium flows which is then heated. In the case of thermal oil plants, temperatures of just under 400 degrees Celsius are possible which are used in a heat exchanger to generate steam, which in its turn drives a turbine. Distinct improvements in quality and savings potential could be demonstrated through advances in research and development of different components such as the receiving pipe or turbine components.

Figure 8: Funding for solar thermal power plants
(See data in Table 2)



In the case of solar tower power plants, solar energy is captured by a heliostat field and concentrated on a receiver in the tower. The solar field with its mirrors and drive continues to be the greatest cost factor. Research work is therefore concentrated on optimising the heliostats and their control.

The strategic research funding of the BMWi contributes to accompanying the role of German enterprises as technological market leaders in global competition. A fundamental goal is to reduce the costs of electricity from solar thermal power plants through innovative component developments. With this aim in mind, projects are funded in the areas of parabolic trough systems, Fresnel systems, solar tower power plants and suitable storage technologies. In addition, the new developments, such as in heat transfer mediums or receiver technology, must be tested not only in simulations but also in prototypes and demonstration facilities. The DLR maintains a demonstration facility of this nature in Jülich.

In 2016, the BMWi approved 13 new projects with a total volume of around 8.9 million euros in the area of solar thermal power plants. A total of 8.58 million euros has now been spent on ongoing projects (see Figure 8).

It is of central importance for the economic efficiency of solar tower power plants for the investment costs to be further reduced without compromising on optical quality. Up to half of the total investments here are expended on the heliostat field. Cost-cutting potential is being examined by researchers in the HELIKONTURplus project coordinated by schlaich bergermann partner – sbp sonne GmbH (sbp). The defined objectives are to be achieved by optimised heliostat contours and an adjusted tower and field design.

2.1.8 Hydropower and ocean energy

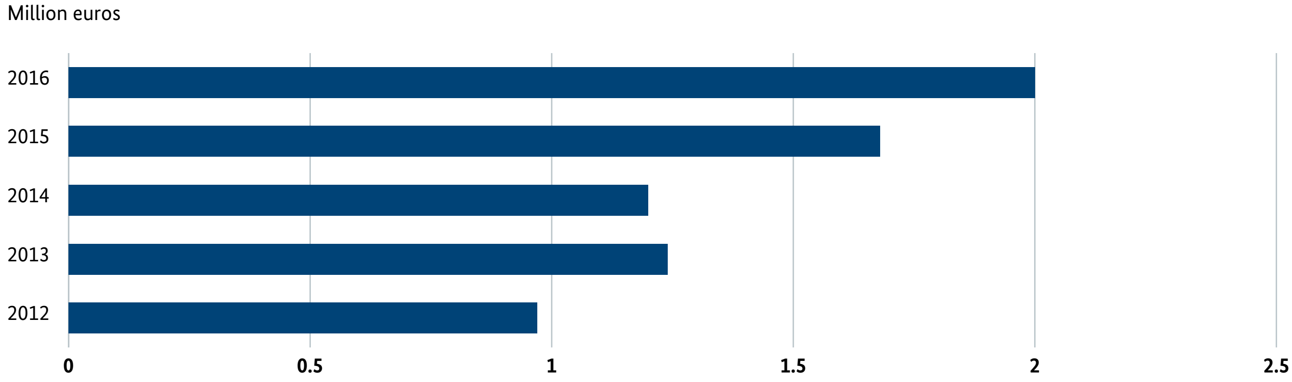
In Germany, turbines or run-of-river wheels at many rivers or dams convert the natural flow of water firstly into mechanical and then into electrical energy using generators. In the oceans, both the tidal lift, the periodical fall and rise of the ocean level and the energy content of the waves can be used for power production.

In Germany, onshore hydropower contributes around three percent of electricity supply per annum. Ocean energy plants are still at the development and testing phase. Ocean flows are primarily caused in coastal regions by the tides primarily. Under certain topographical conditions, the flow can be used to generate electricity.

Both onshore hydropower and ocean energy are constantly available as a source of energy in many countries. Even if the European ocean energy industry expects an installation of maritime systems with a total output of only some 300 megawatts by 2020, research is significant with a view to the global markets for German mechanical engineers. For this reason, universities, research institutes and industrial enterprises in Germany are addressing different issues presented by the ocean energy sector.

The BMWi primarily focusses its research funding in the area of established hydropower technology on improving the degree of efficiency of turbines. Research projects are also supported which deal with the ecological compatibility of technology. Unlike onshore water use, ocean energy technologies are still at the developmental and demonstration stage.

Figure 9: Funding for hydropower and ocean energy
(See data in Table 2)



In the area of hydropower and ocean energy, the BMWi approved a total of 4 new projects in 2016 with a funding volume of 3.51 million euros. At the same time, 2.01 million euros were spent on ongoing research projects (see Figure 9).

By contrast with tidal power plants, in a wave power plant the energy of the wave motion is used and not the ocean flow energy from high and low tide. In the NEMOS wave power plant, up to 20 metre long floats are linked by way of a special rope and pulleys to a generator which is positioned in the dry, for example on a tower, protected from salt water. The generator therefore remains easily accessible and the costs which arise from the strong wear of components in salt water are reduced. The NEMOS collaborative project funded by the BMWi is coordinated by the NEMOS undertaking in Duisburg.

2.2 Energy distribution and energy use

2.2.1 Storage

Energy storage is a relevant flexibility option for the energy system. It enables fluctuations produced from the infeed of renewable energies to be balanced out in the supply grids. This creates leeway for the further advancement of the energy transition and increases the dynamics and stability of the electricity system by taking up surplus and releasing it again into the distribution grid at peak times.

Storage is also an important interface for the interlinking of electricity, thermal, refrigeration and transport sectors. Grouped under the term "sector coupling", synergies are emerging between markets which have been separate up to now, leading to a more flexible system with high shares of renewable energies.

All in all, electrical storage facilities have continued to develop positively on the market. For 2016, analysts expected the market volume for storage systems to double to a globally new installed storage capacity of around 2.9 gigawatt hours. Battery systems could reach storage parity by 2017. This means that the generation costs for electricity generated in a PV system and stored are equal to the costs for traditional household electricity from utility companies. This is made possible by a decrease in costs per kilowatt hour and an increase in the capacities for PV home storage.

Power-to-gas is an important focal area of the BMWi's applied storage funding because this method is still very cost intensive. Projects such as GreenH2 aim to alter this situation and to generate hydrogen inexpensively, load flexibly and sustainably. The development of a competitive stack production in Germany is also one of the objectives supported by the Ministry. Several collaborative projects, such as NeStPEL, are conducting research into this area.

The BMWi also supports the further development of battery systems, such as lithium ions or redox flow, in its funding of energy storage projects, supplemented by pressurised air, hydrogen and oscillating wheel storage facilities as well as super condensers.

For example, compressed air storage systems are interesting as power plants which can be controlled quickly because on the one hand they are able to take up surplus electricity and to use the thermal energy as adiabatic storage. In this way, they can balance out daily fluctuations and participate in the regular energy and capacity market. In the long term therefore and in combination with renewable energy plants, they can replace conventional power plants. Their greatest potential lies in the large storage of up to a few gigawatts. The costs here are comparable with those of pump storage. In the area of pump storage, new options could arise for the energy transition - by retrofitting former coal mines, for example. The University of Bochum is conducting investigations with two partners in the UPSW2 collaborative project to determine how a system of this type could be implemented economically and technically underground.

Digitalisation plays an important role in the integration of energy storage. The green2store collaborative project (see below) is financially supported in the Energy Storage funding initiative and examines the use of intelligent ICT solutions for storage systems.

The BMBF funds projects of applications-oriented basic research in the area of energy storage to prepare the way for the storage technologies of tomorrow. One example is the silicon-air battery which can achieve theoretically far higher energy densities than today's lithium ion batteries, permitting distinctly higher electric car ranges. Silicon is also low cost and environmentally friendly with virtually unrestricted availability.

The BMBF funds research on this trend-setting technology in the AlSiBat collaborative project. In July 2016, researchers of AlSiBat for the first time reported a record lifecycle of over 1,000 hours for a silicon-air battery.

BMBF project funding addresses storage technologies on a broad front: in addition to batteries and super condensers as well as thermal storage facilities, concepts are also advanced which use the generation and storage of hydrogen, methane or synthetic fuels (for example methanol) and which are superior to all other storage types in terms of their capacity as power reserve (power-to-gas, power-to-X). Their key component of hydroelectrolysis is the subject of the MANGAN cluster project, which investigates the technical potential of manganese as a highly available and favourably priced catalyst for the sub-processes of water splitting. Doing without expensive precious metal catalysts would be a decisive step towards the success of the power-to-gas storage concept.

In addition to an involvement in the Energy Storage funding initiative (see below), BMBF storage funding also covers projects as part of the Materials Research for the Energy Transition funding initiative (see Chapter 2.3.8) as well as parts of large-scale projects in the subject area of power-to-X/electrolysis (MANGAN, Carbon2Chem – see Chapter 2.3.5, Copernicus P2X – see Chapter 2.3.4). Alongside the BMBF activities in the 6th Energy Research Programme, further funding programmes of the BMBF also make a contribution to innovations in storage technologies, such as the From Material to Innovation programme (see Chapter 4.1.7).

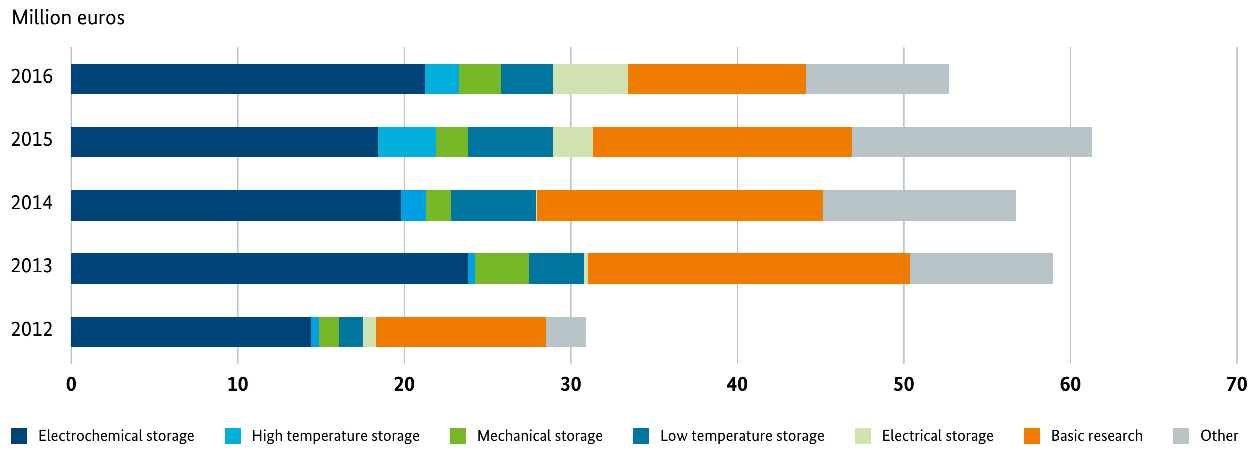
In 2016, the BMWi and the BMBF funded 395 ongoing projects in the field energy storage and approved 109 new research projects. The ministries expended some 53 million euros in the funding of ongoing projects. The new approvals have a total funding volume of 56.98 million euros.

Energy Storage funding initiative

A total of 259 research and development projects, from basic work through to applications-oriented demonstration projects, are supported by the BMWi and BMBF as part of the Energy Storage funding initiative. It is emerging that this initiative is proving successful in improving cooperation between the scientific world and industry in the area of energy storage and moving towards an acceleration of the development of storage technologies through a strong increase in funding. In addition to the individual successes achieved in storage research, the funded demonstration projects have also provided important stimuli for scaling up the technologies and developing concepts and business models. However, it has also been shown that further technological innovations are necessary for economic success in the long term. It must also be said that business models tend to be associated more with political than with technological framework conditions.

Within the initiative, the BMWi funds applications-oriented research. One of the successful projects is green2store. In this project, the parties involved developed an integrative, virtual electricity storage facility. The Energy Storage Cloud provides storage capacities for energy traders, plant operators and consumers following the principle of cloud computing. In this way, a broad variety of stakeholders can use energy storage without having to have it themselves. Concentration also permits a higher utilisation of capacity of the individual storage sources.

Figure 10: Funding for storage
(See data in Table 3)



Within the applications-oriented basic research projects funded by the BMBF, mention should be given to the successes achieved in the research into catalysts for hydroelectrolysis (significant reduction in the expensive share of precious metals, ELY-KAT project) and a new combined hydrogen and heat storage system for fuel cell apparatus in the area of buildings, which was presented by the researchers in the HD-HGV project at the Hannover Trade Fair in 2016. It has also been possible to record basic success in battery research. For example, researchers in the ChryPhysConcept project have uncovered foundations for a new aluminium-ion solid battery. This technology, the potential of which – similar to the above mentioned silicon-air battery – is distinctly higher than that of the lithium-ion battery, is to be advanced in the direction of an application in a joint venture of industry and research as part of the BMBF's Materials Research for the Energy Transition initiative.

2.2.2 Power grids

Power grids combine the generation, storage and consumption infrastructure, permitting the exchange and distribution of energy. The move away from fewer central conventional power plants towards many decentralised renewable energy plants is evident in the energy transition. This move increases the systemic significance of transfer and distribution networks as a central coordinating element and brings with it a rise in regulatory requirements.

A suitable grid infrastructure and flexible operating strategies are required in order to balance out generation and consumption whilst at the same time keeping frequency and voltage constant. The integration of fluctuating capacities generated from renewable energies into the system therefore requires the conversion and expansion of the transfer grids for the highest voltage and of the distribution grids for high, medium and low voltage as well as the use of innovative components and materials. Smart grids are also intended to permit an efficient fine tuning between electricity producers and consumers and therefore at the same time to reduce the need for grid expansion. Digitalisation is also producing further potential for a flexibilised and dynamic operation. At the same time, however, new issues are arising such as that of data security and storage or the compatibility of the information and communication technologies used. The legal framework was created by the Deutsche Bundestag in June 2016 with the Act on the Digitalisation of the Energy Transition and the Act on the Further Development of the Electricity Market. The technical and conceptional hurdles must now be overcome through research and development.

One of the BMWi's priorities of applied project funding for power grids therefore refers to projects which address the impact and potential of a digitalised grid infrastructure. This includes the development of new control and regulation strategies and grid management systems for smart grids in the same way as the definition and standardisation of interfaces for data exchange, data storage and security, forecast procedures, bidirectional energy management and also research projects on power trading, grid planning and system simulation. In this context, the BMWi funds projects such as FlaixEnergy which, for example, creates an energy flexibility platform to synchronise and market the regional electricity consumption of industrial users. It also funds the uGRIP project, an international group within the ERA-Net Cofund Smart Grid+, that examines the system-expedient behaviour of microgrids through local markets.

The power grid of the future will require innovative powerful electronic components. To this end, the BMWi published a call for proposals in 2015 from which 16 projects emerged which were largely started in 2016. This also includes the DC-INDUSTRIE project in which an intelligent open direct current grid (DC grid) is produced that can distribute energy as it is required within industrial production plants.

Other funding topics include IT-assisted forecast procedures so as to be able to reliably predict the weather as a decisive influential factor on the yields of wind and solar power plants and therefore also on the operation of the grid infrastructure. The EWeLiNE collaborative project addressed this topic with innovative weather model calculations, successfully completing the work in November 2016.

In future, renewable energy plants will increasingly have to provide system services which are currently provided by traditional power plants. This includes wind or solar power plants supporting the frequency and voltage maintenance in the grid or providing reactive power. New concepts and technical solutions are also required here which are supported by funding. What is more, a system with a large number of inverter-based generation plants makes other planning and operational resources necessary than have so far been required in power plant parks. A BMWi-funded project in this respect is the Distribution Grid 2020. The project addresses components that guarantee the maintenance of voltage and grid quality even with a high share of renewable energies.

An important element for the further development of the BMWi funding strategies is the Power Grid Research Network, which was re-established at the start of 2017 and brings together 120 experts. In future, greater focus will be placed on subjects of digitalisation in particular and they will be better networked.

BMWi and BMBF approved a total of 119 new projects in the area of power grids in 2016 for a total of some 53.23 million euros. Some 70.93 million euros were expended on the 620 ongoing projects.

The Future-proof Power Grids research initiative

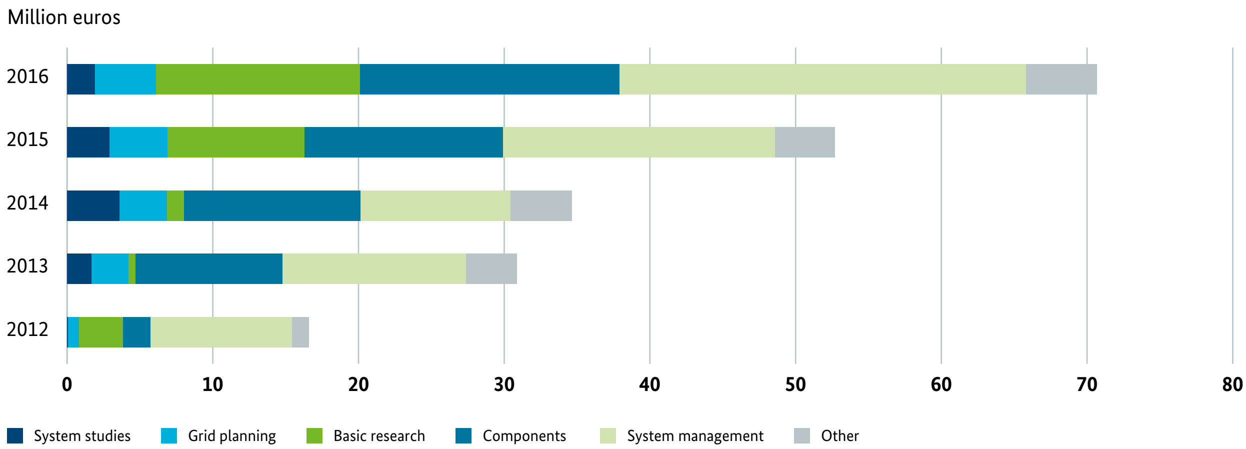
BMWi and BMBF fund the development of innovative procedures, concepts and materials for strong grids in the energy transition with the future-proof Power Grids research initiative of the Federal Government. The interdepartmental initiative is part of the 6th Energy Research Programme and is intended to create the necessary technical foundations for smart distribution and transfer grid structures as well as dynamic grid planning and grid operation.

The funded projects pursue innovative concepts for more efficient power grids which are indispensable for a successful energy transition. The projects funded by the BMWi include the eSafeNet collaborative project in which a consortium is developing an energy-efficient and safe communication network for the internet of energy that integrates all stakeholders in the energy industry and intelligently interconnects them using reliable ICT transfer technology.

The BMBF similarly funds projects which help to adapt the grid infrastructure to the altered framework conditions of the energy transition through developing efficient components (HV-SiC) or innovative direct current concepts (DC-Direkt). All in all, the funded projects are aimed at making the best use of the existing grid infrastructure and largely avoiding an extension of the grid which would otherwise be necessary. Approaches are also considered in which the system stability, the requisite grid protection or the increasing demand placed on grid monitoring and diagnosis are of prime importance. Examples of these projects are the Grid Sensors project and the CoNDyNet project. Grid Sensors attempts to make conclusions from existing information of data communication as to the condition of the grid infrastructures using broadband powerlines (BPL). It has already been possible to identify first systematic correlations. The project was presented to a broader public in June 2016 as part of the Environmental Week staged by the Federal President. CoNDyNet uses mathematical methods from theoretical physics to explore non-linear collective phenomena in power grids, such as resonance effects, as part of a holistic approach. The free simulation software PyPSA was prepared and published with a model of the German electricity system in the project, which quickly developed into a new standard in the research community and is now also being used throughout the world.

A first status conference on the funding initiative took place in September 2016 with more than 300 stakeholders from the scientific community, industry and society.

Figure 11: Funding for grids
(See data in Table 3)



In addition to presenting the projects and the results so far obtained, keynote papers were held and podium discussions staged to discuss the challenges and opportunities presented by a decentralised grid. The experts also discussed topics such as system services, information and communication technology, their security as well as grid planning and grid expansion. Further areas of focus included experience on the collaboration between the scientific world and industry and the possibilities of transferring technology to practice.

2.2.3 Energy efficiency in industry, commerce, trade and services

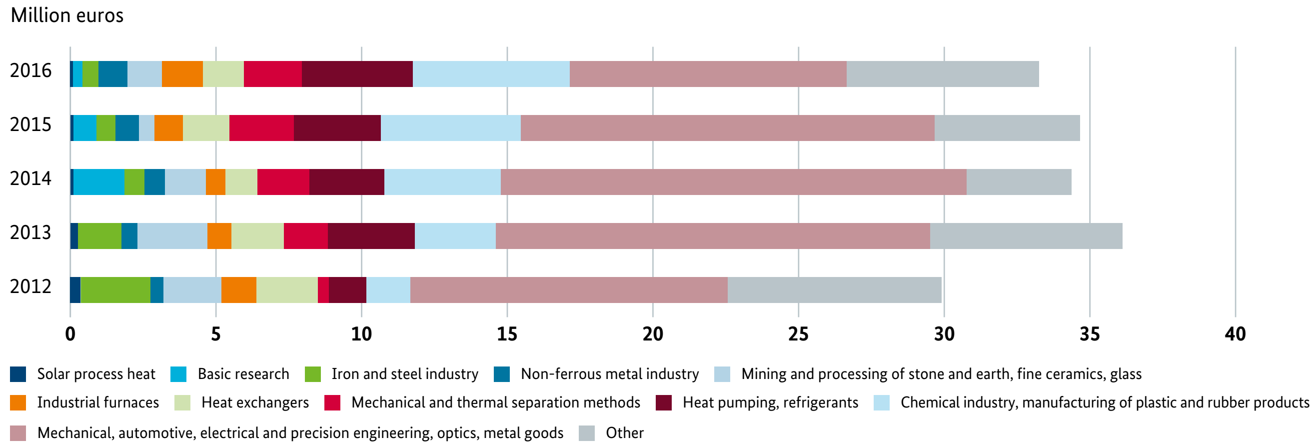
Sectors such as mechanical engineering, automotive, electrical engineering, building materials, chemicals, glass, paper or iron and steel are among the large industrial energy consumers in Germany. They account for some one third of all energy consumed in Germany. The associated carbon emissions are correspondingly high. Those companies which do not save energy or offer energy-efficient products, services and processes will find it more difficult in future to assert themselves on the market. The savings potential in the different sectors is broad, ranging from drives, motors and pumps through mechanical and thermal processing steps to horizontal technologies and newly shaped production processes. The BMWi funds the research and development of energy-efficient technologies that go gentle on resources across the entire industrial sector, thereby strengthening the position of German participants in international competition.

Energy research in the funding area of energy efficiency of industry, commerce, trade and services is characterised by a broad thematic and technological diversity. In order to facilitate selective research and development here and keep funding measures efficient, the BMWi established the Energy in Industry and Commerce Research Network in 2016 with the following seven areas of research: chemical process technology, high-temperature supraline, tribology, production technology, waste heat use, gas and industrial motors as well as iron and steel. In future, strategic key subjects of the industry and commerce research area will be concentrated in these theme-specific research fields to create important synergies in the long term. As an interface between research, politics and practice, the research fields permit a scientific dialogue on specific topics, long-term research collaborations and programmatic further developments.

The Federal Government's project funding in the area of energy efficiency in industry, commerce, trade and services was some 33.70 million euros for 379 ongoing projects in 2016 (see Figure 12). 115 new projects were approved with a funding volume totalling some 56.57 million euros.

The developments in energy optimisation of individual machines and plant components are now virtually exhausted in many areas. This is why entire process chains in manufacturing and the interaction of energy from raw material to the finished product are at the centre of research funding. As an example of the activities in the new research field of production technology, the ETA factory was opened

Figure 12: Funding for energy efficiency in industry, commerce, trade and services
(See data in Table 3)



at the Technical University in Darmstadt in March 2016. The demonstration project funded by the BMWi to the tune of some 8 million euros shows how the primary energy requirement in process chains can be reduced by way of an example of a production chain typical of the metals processing industry.

The BMWi-funded research project High-TEG (research field of waste heat use) is also to be emphasised, which was given the German sustainability award in November 2016. Researchers developed a new process here using which thermo- electrical models can be industrially produced at a favourable price.

A further award winner in 2016 is the AmpaCity research project (research field of high temperature supraline), funded with some 5.9 million euros, which received the German innovation award for climate and environment for the world's longest section of a high temperature supraline.

2.2.4 Energy in buildings and cities

Around one third of the total energy consumption and carbon emissions in Germany is attributable to homes and non-residential buildings. There is an enormous potential for reducing energy consumption in this area and efficiently covering the remaining requirements by renewable energy sources.

The Federal Government declared its goal in the Energy Efficiency Strategy for Buildings (ESG) of making the building stock virtually climate neutral by 2050 and consuming some 80 percent less energy than in 2008. Energy research in the 6th Energy Research Programme makes an important contribution here. A large number of technical innovations have already been developed, researched and tested in scientifically supported demonstration projects.

The energy transition of recent years has so far been an electricity transition. Around one half of end energy consumption in Germany is attributable to the generation of heat and refrigeration, however. It therefore becomes clear in this context that the energy transition cannot succeed without a heat transition. Heat consumption in buildings (building-relevant end energy consumption) was reduced by some 11 percent between 2008 and 2015, and in 2015 renewable energies already contributed more than 13 percent to heat consumption in Germany.

Further innovations are called for at all levels to implement the energy and heat transition in the entire building stock. The BMWi funds innovative technologies and concepts on the path towards an efficient and climate-neutral heat and refrigeration supply. Optimised heat networks are an important element here so as to make best possible use of renewable energy sources such as solar energy, geothermal energy and also the infeed of industrial waste heat.

Practical experience is collected in ambitious demonstration projects of typical buildings and cities on the application of innovative technologies and planning assistance, implementation management and operational optimisation. The results and conclusions are scientifically analysed and can be transferred to other projects and locations. An interdisciplinary team involved in scientific flanking research also analyses all ongoing and completed projects in the area of buildings and cities for the networking of research areas in addition to demonstration projects. The scientists provide planning tools, project-specific ratios and results from the monitoring of the projects in an interactive "project map" – a database which can be used by all interested planners (also outside the research projects).

One growing area of research for buildings and cities is currently information and communication technology (ICT) because innovative building technology and intelligent electrical, thermal and digital networking can make a decisive contribution to optimising the energy used in buildings and cities. Modern planning tools are also gaining importance in new buildings, refurbishment and also ongoing building measures. There are specialised software and tools here as well as innovative approaches of building and plant simulation.

Innovative, efficient and economical supply structures are primarily at the focus of research funding for energy-optimised buildings and cities. Systemic approaches instead of individual solutions are called for to advance sector coupling and digitalisation and to significantly reduce the primary energy demand in the entire system by integrating renewable energies.

In the area of buildings and cities, some 53.60 million euros were provided by the Federal Government in 2016 for 549 ongoing projects of energy research. 148 new projects with a funding volume of 69.19 million euros were approved in 2016.

In 2016, the BMWi brought together the former funding areas of Energy Optimised Buildings (EnOB), Energy-efficient Cities (EnEff:Stadt) and Energy-efficient Heat (EnEff:Wärme) including research on thermal energy storage and low temperature solar thermal energy under the ENERGIEWENDEBAUEN research initiative. The calls for proposals EnEff.Gebäude.2050 (see Chapter 4.1.4) and Solar Building/Energy-efficient Cities (see below) published in April 2016 also fall within this heading.

A new approach in energy research was pursued with the BMBF competition for energy-efficient cities and towns. Technical, administrative and socio-scientific issues involving all stakeholders (municipalities, research and industry) in the cities and towns were considered. The final event of this initiative took place in 2016.

The five winning cities and towns took the path to energy and resource-efficient, climate-friendly and social cities of the future with the assistance of the funding:

Delitzsch engaged in sustainable urban development in collaboration with its citizens. An Energy Efficiency Masterplan was developed which features the most effective measures for each individual part of the town. In 2015, the town was then given the European Energy Award Gold.

In Essen, a city in the Ruhr region, the climate agency is the driver for a new climate culture. 100 craftsmen and local enterprises as local partners have made climate protection and energy efficiency their business model, around 150,000 citizens found out about measures and almost 50,000 advisory meetings were conducted on the implementation of projects. Based on these results, Essen will become Europe's Green Capital in 2017.

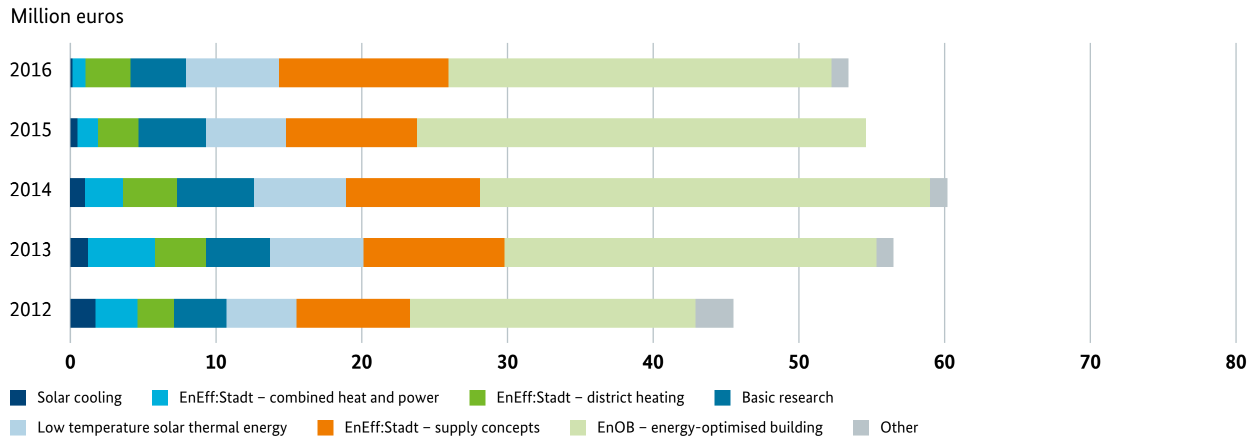
In the regional capital of Magdeburg the focus was placed on the traffic sector. An intelligent traffic management system now controls traffic lights, organises delivery traffic with electric cars and improves routing and connection of the public local transport system. The traffic flow is reduced and optimised as far as possible, and exhaust gases reduced.

The regional capital of Stuttgart developed 100 energy-efficient measures together with its citizens. The share assumed by renewables has therefore doubled within four years and carbon emissions have been reduced by one tenth. The new energy concept - Urbanisation of the Energy Transition in Stuttgart - was prepared on the basis of these measures. Stuttgart is seeking to become climate-neutral by 2050.

Wolfhagen has been producing more power from renewables than it needs since 2015. Wolfhagen has become a model town for renewable energies and attracts groups of visitors from all over the world. The professional college centre with the transparent solar roof is known beyond regional borders. In the "Wandelbar", citizens can get involved and find out about energy-efficient measures. As part of the project, a citizens' foundation was established in 2015 and the Wolfhagen citizens asked to continue to contribute to shaping new measures with their ideas.

The BMBF has earmarked 25 million euros for the competition.

Figure 13: Funding for energy efficiency in buildings and cities and low temperature solar thermal energy
(See data in Table 3)



The BMBF funds innovations at the material level in the Materials Research for the Energy Transition initiative. For example, a new class of nano insulation materials in the form of non-woven material made of nano fibres has been developed as a high performance insulating material in the NanoFIM collaborative research project. The materials permit improved insulation of building and insulating materials for use in new buildings or for the refurbishment of old ones. The development of an innovative insulating material on the basis of the biopolymer cellulose acetate, which can be obtained from the sustainable raw material of wood, is the objective of the CA Flame Protection collaborative project. Urgent questions of fire protection are addressed here in particular.

Interdepartmental research initiative: Solar Building – Energy-efficient Cities

In April 2016, the BMWi and the BMBF published the interdepartmental funding initiative entitled Solar Building/Energy-efficient Cities. With a funding volume of up to 150 million euros, it addresses projects that show how innovations and intelligent networking of energy-optimised buildings and cities that are worth living in can arise. In addition to technological aspects, socio-ecological and socio-economic aspects are given particular consideration. The measure represents the contribution of energy research to the Future Cities umbrella initiative and is flanked by the EnEff.Gebäude.2050 funding initiative which is intended to bridge the gap between research results and ready-for-market applications by way of model projects. As part of the Energy and Climate Fund (EKF), it provides a further 35 million euros for model innovation and transformation projects and for an ideas competition on buildings and cities of the future.

The Solar Building/Energy-efficient Cities funding initiative has a modular structure. In the Solar Building Module 1, the BMWi funds ambitious collaborative projects which - through a combination of research, development and demonstration - contribute to implementing the Federal Government‘s Energy Efficiency Strategy for Buildings (ESG) for multi-storey residential buildings in renovation measures and for new builds. In the Energy-efficient Cities Module 2, the BMWi and BMBF together fund comprehensive systemic lighthouse projects in cities. They are intended to show that an overall energy concept incorporates all relevant stakeholders from basic research through to implementation. Broad-based consortiums of municipalities, research institutes, representatives of society and businesses such as utility companies and residential building companies are to join ranks for this purpose. Energy consumption is to be reduced, sector coupling advanced and the entire system gradually decarbonised by integrating renewable energies. Funded projects are to make a decisive contribution to the local energy transition and in particular to the local heat transition. These scientific and technical issues in the research projects are to be extended particularly by considering socio-scientific and socio-economic aspects such as the demographic change in society, calls for affordable living space in areas of conurbation and the involvement of the general public. The objective is to obtain visionary and viable future concepts which show how flexible and high quality energy-efficient living space can be economically created combined with an optimised energy infrastructure.

The Energy in Buildings and Cities Research Network and the Research and Innovation Agenda (FINA) of the National Platform Future Cities (NPZ) provided valuable stimulus for the interdepartmental funding initiative.

2.3 System-oriented energy research and horizontal issues

2.3.1 System analysis

The system analysis provides basic information that can reflect, analyse and forecast the entire value added chain of energy supply. Using models and simulations, it creates the foundation for planning a stable and reliable interaction of all elements and components of the energy system. It acts in an ever more complex research field, influenced by technical, ecological, economic, socio-economic and political factors which impact the structure.

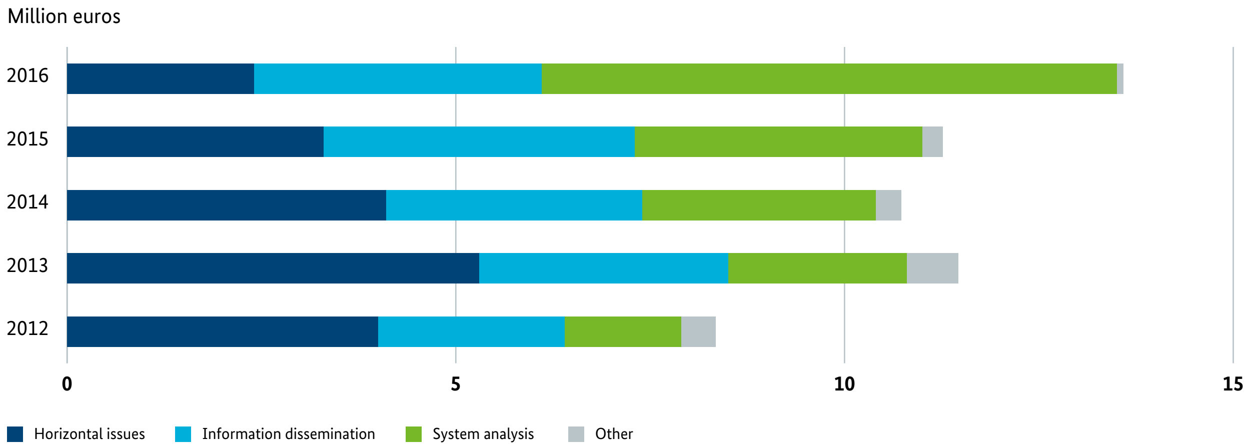
Digitalisation opens up new potential for the system analysis thanks to network system components and the occurrence of large volumes of data (big data). For example, a broader calculation foundation can make models more realistic and simulations more comprehensive. They help to plan more precisely the mode of action and integration of individual energy technologies. The necessary tools are developed by research into inter-disciplinary complexes.

As the demand for system networking and integration becomes greater, research concentrates on open source and open data procedures. These freely available options align models and simulations to a greater extent with actual market circumstances and make them more precise and comprehensive. There is still a great need for research and development in this area so as to design the large number of software systems, data and parameters as well as programing languages to make them comparable and compatible.

Sector coupling also creates new demands on system analytical research in terms of the detailed knowledge required and more precise forecasting methods. The flexible exchange between the electricity, heat, refrigeration and gas market and traffic will become more important in the energy transition so as to be able to use power-to-X methods, for example. Coupling permits the interaction of system elements beyond sectoral borders and contributes to greater supply security. Greater data networking and a more comprehensive planning foundation are necessary to incorporate new technical applications and take into consideration of short-term, medium-term and long-term influential factors.

The importance of socio-economic factors increases with the energy transition. Modelling and planning tools therefore focus on them in particular because they permit valuable information to be obtained on which technologies and efficiency measures can also become established amongst users.

Figure 14: Funding for system analysis and horizontal issues
(See data in Table 4)



The analysis of the potential presented by energy systems, technologies and concepts also remains an important pillar of system analysis. In a technical-economic evaluation, scientists can increasingly refine their models and make them more detailed. The system analysis can therefore reflect reality better and generate future-proof forecasts, facilitating a better economic and political planning of energy.

In 2016, the BMWi approved 67 new projects on system analysis with a funding volume of some 27 million euros. Moreover, some 13.67 million euros were spent on 147 ongoing research projects (see Figure 14). The overwhelming majority of the new research work originated from a call for proposals by the Ministry on modelling issues.

2.3.2 Energy Transition Research Alliance in Industrial Community Research (IGF)

In the years to come the BMWi will provide a total of 30 million euros additionally from the budget for energy research to fund Industrial Collective Research (IGF) projects with relevance to the energy transition. The Energy Transition Research Alliance established in 2016 supports pre-competition research and development of energy innovations for small and medium sized enterprises (SMEs) and serves as a dialogue platform and a new cooperation model of energy research. The initiative is intended to form a bridge from the research laboratory to applications in SMEs. The research projects must be assignable to the priorities of the BMWi's energy research in the 6th Energy Research Programme. There is special interest in projects on the digitalisation of the energy transition and on intelligent sector coupling. The research advisory council of the Energy Transition Research Alliance identifies research projects of special relevance to the energy transition and proposes them for funding. The advisory council is composed of experts from industry and the scientific world who in their turn are broadly networked in the German research and development landscape. They are representatives of the BMWi, of the AiF and of participating research associations.

Two projects were first launched in 2016 as part of the Energy Transition Research Alliance which address power electronics optimisation in the formatting of battery cells and insulated double pipe systems for distant heating networks. New project outlines can be submitted at any time.

2.3.3 Sector coupling: energy transition for transport

Sector coupling, i.e. the use of electricity from renewable energies to generate heat, refrigeration and drive energy, is a subject that is becoming increasingly important also in energy research. There is a considerable need for basic research alongside applications-oriented research questions precisely in the area of synthetic fuels and the BMBF and BMWi are addressing this topic. In 2016, the BMWi therefore prepared the funding initiative entitled Energy Transition in Transport: Sector Coupling by the Use of Electricity-based Fuels. This initiative is intended to fund the stronger networking of the energy industry, transport sector and maritime economy. The focal emphasis of the research initiative is placed on research projects for the production and use of alternative, electricity-based fuels and the incorporation of the new technologies into the energy industry. Electricity-based fuels can be used in cars, trucks, ships, construction machines or in stationary industrial motors. Starting from an intersector approach, funding will also be provided for research and development for maritime systems with synthetic fuels and for smart microgrids in port areas. The call for proposals refers to research, development and demonstration of innovative energy and transport technologies and places a special focus on applications in the maritime economy.

Besides the Energy Research Programme, the New Vehicle and System Technologies and Maritime Technologies research programmes are also involved. The BMWi has earmarked some 100 million euros for energy research here.

2.3.4 Copernicus projects

A new approach in research funding was successfully launched in 2016 in the form of the Copernicus projects. Through cooperation of partners from science, industry and the civil society a bridge is built from basic research to applications on a large scale. This is why the initiative has a time framework of ten years so that research work can be consolidated and not restricted to two to five years as is frequently the case. For the first phase, the BMBF has earmarked 120 million euros for applications-oriented basic research. Two further project phases are foreseen up to 2025 which are to be funded with a further 280 million euros. The mobilisation effect is considerable: more than 250 partners collaborate in the four projects.

The subjects are the conversion of surplus renewable energy into other energy sources such as hydrogen, the development of power grids which are attuned to a high share of renewable energies, the re-alignment of industrial processes with a fluctuating supply of electricity from wind and photovoltaics as well as the interaction between renewable and conventional energies to secure an uninterrupted supply of energy.

2.3.5 Carbon2Chem

The Carbon2Chem project researches the use of smelting gases in chemical products. Using the waste gases from steel production, up to 20 million tonnes of carbon emissions could be cut annually in Germany alone. What is more, a climate-relevant carbon savings effect is achieved for the first time.

Leading German companies from the chemicals, steel, energy and automotive sectors have joined ranks with universities and research institutions to implement the ambitious goals of the ten year research project. A broad collaboration of national key industries with institutional research is therefore funded in "Carbon2Chem". The project researches both the aspired-to implementation processes for different chemical target products, the provision of large volumes of regeneratively produced hydrogen, the cleaning and preparation of smelting gases for use and the technical implementation in the steel works under consideration of the ecological and economic footprint. Viable use paths are developed in order to sustainably manufacture fuels, fertilizers and plastics.

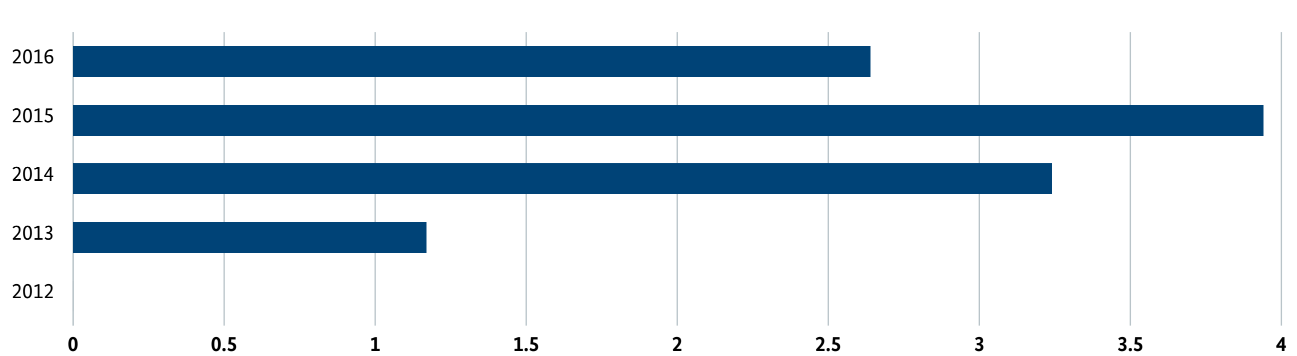
BMBF will provide more than 60 million euros for the first four year funding phase of the project. The partners plan investments of over 100 million euros up to 2025. The funds will be used amongst other things to establish large scale laboratories which permit experiments with real smelting gases. Furthermore, basic research results will be transferred to applications-oriented research in the areas of electrolysis and chemical catalysis in the first project phase.

2.3.6 Socially compatible transformation of the energy system

Social aspects are of great importance in implementing the energy transition. The energy transition will only be successful if it appropriately reflects the needs and expectations of the general public, industry, commerce and municipalities – also with respect to issues of participation and justice – as well as taking the requirements of the market economy into consideration. This is where the BMBF funding initiative Environmentally and Socially Compatible Transformation of the Energy System comes in. Funding is focussed firstly on presenting and assessing development options of the energy system including economic scenarios. A further important approach is the analysis of the social requirements for the acceptance of the transformation and the active participation of the general public. Just as important is the regulatory framework (governance) of transformation processes including economic instruments.

The BMBF has expended over 30 million euros on the over 30 funded research projects (see Figure 15). The project results and their potential for use were presented and dis-

Figure 15: Funding for socio-ecological research
(See data in Table 5)



cussed in transfer workshops at the final conference in Berlin on 4 and 5 October 2016. The core topics of many research projects were addressed in several discussion rounds, such as the participation of the public in (infrastructure) planning, centralised and decentralised energy concepts, governance of transformation processes and the refurbishment of the building stock in terms of energy consumption.

2.3.7 Materials research for the energy transition

In the context of the energy transition, the development and improvement of materials for deployment in energy generation and use assumes great importance and provides the foundation for innovative energy technologies. These materials should optimise the efficiency of energy generation and also open up applications to regenerative energy sources such as through load flexibility or the use of regenerative fuels. Increasing the efficiency of energy use is also important, for example by innovative insulating materials for buildings or the use of storage. The BMBF therefore successfully initiated the Materials Research for the Energy Transition funding initiative in 2013. By international comparison, the German energy research landscape already has extremely efficient infrastructures. The funding initiative addresses precisely this aspect to strategically network innovative solution approaches of the existing structures with ideas on material issues.

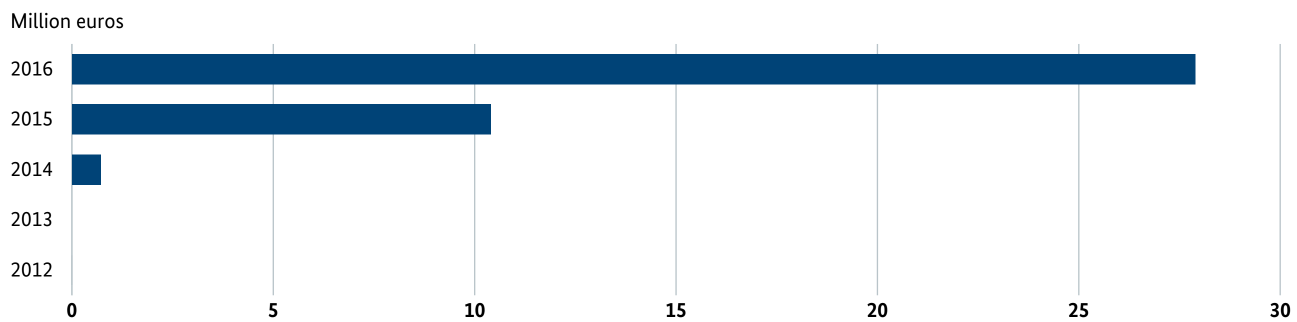
The range of topics of the funding initiative is not confined to any particular technology and extends over all topics in the energy area. Previous funding has been focused on photovoltaics, wind power plants, power plant technologies, energy storage, insulating materials, fuel cells and electrolysis. The funding initiative therefore covers basic projects which prepare the material foundation for a large number of further developments in the area of technologies for energy generation and use for the energy transition.

Seven young researcher groups are funded to support young scientific talent as part of the initiative.

The world's first international zinc-air battery workshop took place on 5 and 6 April 2016. It was organised by the project entitled Zinc/Air Batteries with Innovative Materials for the Storage of Regenerative Energies and Grid Stabilisation – LUZI". In the years to come metal-air storage systems will assume an outstanding role but several hurdles need to be taken before market maturity. With 106 experts from 16 countries, the current status of international research on zinc-air batteries was discussed and debated in terms of how long-life, favourably priced and environmentally friendly zinc-air systems can be further improved.

143 innovative basic projects are conducted in the funding initiative with funding of some 90.09 million euros. 29 projects were launched in 2016 alone with a volume of around 19.96 million euros. Funds were provided for the initiative in an amount of around 27.87 million euros in 2016 (see Figure 16).

Figure 16: Funding for materials research
(See data in Table 5)



2.3.8 Energy Lab 2.0

The Karlsruhe Institute of Technology (KIT) in collaboration with the German Aerospace Centre (DLR) and Forschungszentrum Jülich is setting up a research infrastructure of energy systems in Energy Lab 2.0. Components to generate, convert and store electrical, thermal and chemical energy are interlinked here and form a "real laboratory" together with existing consumers. Wind parks, geothermal plants, electrolysis systems, conventional power plants and industrial consumers are connected by means of information technology, permitting the different energy grids (power, heat, gas, fuels) to be examined in an overall energy system (Smart Energy System) which is as realistic as possible.

The aim of Energy Lab 2.0 is to develop efficiency and flexibility increases in the entire system, thereby making a contribution to the stabilisation of the energy grids.

The total costs amount to around 23 million euros and are borne by the Helmholtz Association (approx. 15 million euros), the Ministry for Science, Research and Art of Baden-Wurttemberg (around 3 million euros), the BMBF (some 2.5 million euros) and the BMWi (around 2.5 million euros).

2.3.9 Dissemination of information

Access to overarching and project-related information is an important factor in supporting the transparency of research funding. The Federal Government meets this aim in a broad variety of ways.

BINE Information Service

The BINE Information Service provides project-specific content of the applications-oriented energy research funded by the Federal Government. The extensive programme addresses a broad professional public from research through to practice in the energy economy as well as representatives of educational establishments. The publications summarise results from research, development and demonstration projects. These include project and topic information as well as a series of technical books. The BINE Information Service also gives technical information and is present on an information stand at selected events.

The editorial department also supports research portals of different funding priorities of the BMWi as well as the interdepartmental funding initiatives of the BMWi and BMBF. Topics include energy efficiency in industry (www.eneff-industrie.info), conventional power plant technologies (www.kraftwerkforschung.info), Energy Storage funding initiative of the Federal Government (www.forschung-energiespeicher.info), Future-proof Power Grids funding initiative of the Federal Government (www.forschung-stromnetze.info/), Energy-optimised Building (www.enob.info), Energy Efficiency in Towns and Cities and on Energy Efficient Heat and Refrigeration Networks (www.eneff-stadt.info and www.eneff-waerme.info). The editorial department provides overarching funding information on research projects on the website www.bine.info and sends out the messages parallel via the BINE Newsletter to some 16,000 subscribers.

Energy research map

The energy research map (http://bmbf.prodata.de/) is drawn up by the BMBF and creates transparency about the achievements of German energy research in the basic research area. It provides a detailed overview of who is working where and with which resources on which energy topics. Energy research is understood to mean any research that contributes to energy topics. The map covers a broad thematic range, such as energy and efficiency technologies, materials research and measurement technologies as well as social sciences.

Fona.de

The BMBF's sustainability research is presented in detail at www.fona.de. FONA (Research for Sustainable Development) prepares decision-making foundations for future-oriented actions and supplies innovative solutions for a sustainable society. Energy research has political priority within the three guiding initiatives of Energy Transition, Green Economy and Future Cities. The website prepares content on sustainability research for a professional public, scientific journalists and an interested general public.

2.4 Fusion research

The Federal Government also advocates fusion research to secure the energy supply in Germany in the long-term. This is because responsible research funding also includes pursuing long-term developments in social, economic and technological fields. The Federal Government therefore continues to support the building of the International Thermonuclear Experimental Reactor ITER in Cadarache (South of France). For the first time ITER is to provide ten times as much energy than needed to heat up the plasma with a fusion plasma in the 500-megawatt range, thereby demonstrating the feasibility of controlled terrestrial energy generation from fusion processes. As one of the seven partners (Europe, Japan, Russia, China, South Korea and India), Euratom represents 27 European states with their own research associations and represents Europe in the ITER Council. During its session in mid-November 2016, the ITER Council agreed with the proposal that the ITER organisation submitted in autumn 2015. Accordingly, the first plasma is to be ignited in the fusion reactor in 2025 followed ten years later by deuterium and tritium cores.

Nuclear fusion is funded in Germany primarily as part of the programme-oriented funding of the Helmholtz Association. The Max Planck Institute for Plasma Physics (IPP), the Karlsruhe Institute of Technology (KIT) and Forschungszentrum Jülich (FZJ) are involved in this programme. In addition, the BMBF has established a time-limited project funding programme focussing on joint projects between research institutes and industry (see Figure 17).

By international comparison, Germany has outstanding scientific expertise in nuclear fusion. Large-scale equipment, such as the Tokamak ASDEX Upgrade and the Stellarator Wendelstein 7-X, which has been in successful operation since the end of 2015 – both at IPP –, the high-temperature helium loop (HELOKA) and the test facility for supraconducting components (TOSKA) – both at KIT – provide a globally unique infrastructure. The IPP coordinates nuclear fusion research of 29 research organisations and universities in 27 European countries as part of EUROfusion (established in 2014).

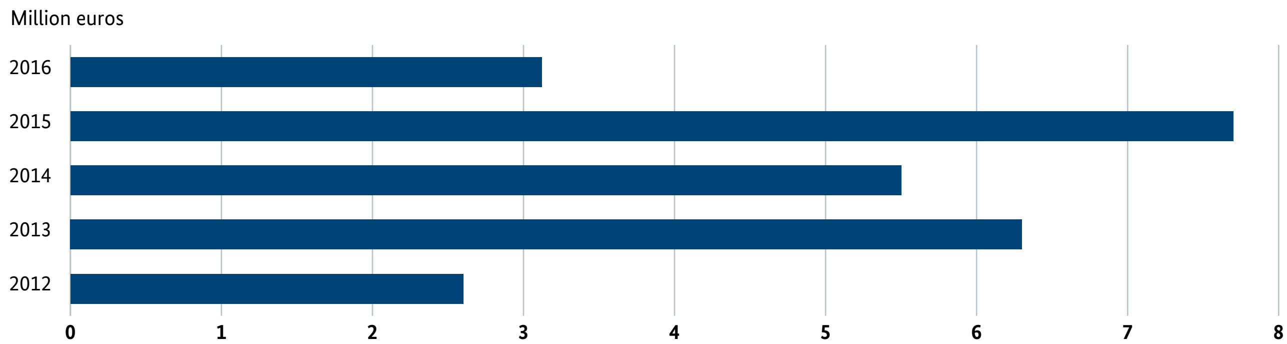
German industrial enterprises take on technologically challenging contracts for the development of ITER, strengthen their international competitiveness and benefit from the collaboration with the research centres and universities. German companies and research institutes have so far received contracts for ITER of over 500 million euros.

2.5 Nuclear safety research

The highest safety requirements apply to the operation, decommissioning and dismantling of nuclear power plants and research reactors as well as to the final disposal of radioactive waste. Section 7d of the German Atomic Energy Act therefore requires that the "advancing state of the art of science and technology" must be maintained. For this requirement to be met, legislators have assigned a prominent role to research and development in these areas. The BMWi heads project funding in the area of nuclear safety and disposal research.

Through selective investments in research and development, the BMWi's funding contributes to creating foundations and further developing the state of the art of science and technology on a long and continuous basis, thereby making a substantial contribution to the development, further development and maintenance of scientific and technical competence. This is especially true against the backdrop of Germany's decision to phase out nuclear electricity generation by the year 2022 because nuclear-related applications in industry, research and medicine are still needed beyond the remaining life span of nuclear power plants in Germany.

Figure 17: Funding for project-related fusion research
(See data in Table 5)



The highest degree of professional expertise and the availability of advanced evaluation methods therefore remain an essential prerequisite for a scientifically sound safety assessment of nuclear power plants and final disposal systems in Germany and abroad.

The BMBF selectively funds the maintenance and enhancement of expertise in the areas of nuclear safety and disposal research and radiation research. Funding is centred on young scientific researchers, promoting the networking of science and industry as part of basic research.

2.5.1 Reactor safety research

Reactor safety research is part of the provision of vital public services to protect the population and the environment against the dangers of a possible release of radioactive materials from nuclear power plants. The objective of reactor safety research is to back-up the safety concept for German nuclear power plants even under phase-out conditions and to contribute to the steady development of safety standards of nuclear power plants worldwide through international cooperation.

In the BMWi funding area of Plant Behaviour and the Cause of Accidents, two important projects were taken into a new project phase in 2016 at German large-scale test facilities. Both projects are conducted under the patronage of the OECD/NEA with significant financial participation from international partners. Issues of significance to safety technology in connection with the operation and also with possible incidents and accidents of light water reactors are investigated. With this aim in mind, experiments on the behaviour of the cooling cycle of a pressurised water reactor are conducted at the primary coolant loop test facility (PKL) in Erlangen. By contrast, the atmosphere of the safety containment of nuclear power plants is at the centre of experiments conducted at the THAI facility in Eschborn. Both projects have increased the number of participating international partner organisations once again, indicating the excellent quality of the research work and the high international relevance of the issues concerned.

The research results of experimental projects will be used both nationally and internationally to improve modern calculating programs. These calculating programs are important tools for the safety assessment of nuclear power plants. One example here is the AC2 program system in which different German calculation codes are compiled. AC2 and its program components have been consistently further developed for many years and are now used worldwide by authorities, experts and research institutes to simulate incidents and accident sequences in nuclear power plants. Using AC2, German scientists also contribute to gaining a better understanding of the effects of the reactor accidents in Fukushima Daiichi and to providing the Japanese authorities with support in decommissioning the damaged plants.

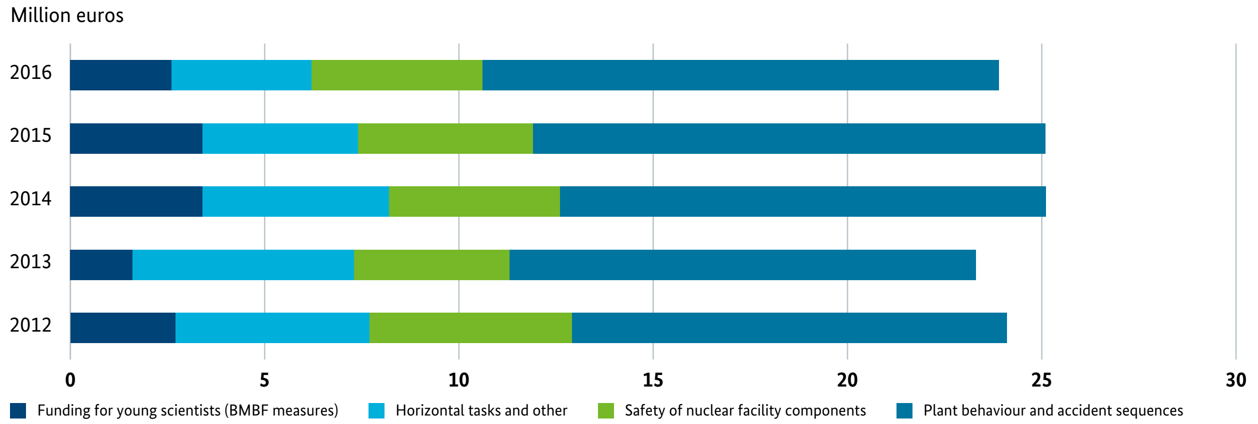
In the subject area of Safety of Components of Nuclear Power Plants, a broad range of materials, structures and procedures are investigated – from the concrete structures of the building shell through metallic components in the inside of the nuclear power plant to suitable integrity testing methods. In 2016, for example, numerical and experimental investigations into the behaviour of reinforced concrete components under fire from different model weapons will be completed. In addition, new findings of the Master Curves for Dynamic Burdens collaborative project have been brought together into an internationally significant ASTM standard which defines a method for the safety assessment of metallic components.

In 2016, the BMWi funded 137 ongoing projects on reactor safety research and around 180 scientific employees (full time equivalents). 27 new projects were approved with funding totalling 17.2 million euros.

The BMBF supplements BMWi research funding with projects in which scientific knowledge in the area of reactor safety research is broadened and further developed in accordance with the BMWi's funding priorities and which primarily serve to train young scientists.

In 2016, for example, the BMBF funded projects which refer to the measurement characterisation of multicomponent aerosols, the investigation of safety systems of light water reactors, safety analyses in the wet storage of fuel elements and the safety assessment of passive systems in the control of incidents. 40 young researchers (PhD candidates, post PhD candidates, masters students) were funded in ongoing projects. No new projects were approved in 2016. In the area of reactor safety research, research projects were funded with some 24.06 million euros in 2016 (see Figure 18). Of this figure, 21.38 million euros were provided by the BMWi and 2.68 million euros by the BMBF.

Figure 18: Funding for reactor safety research
(See data in Table 6)



2.5.2 Nuclear waste final storage and disposal research

The foundation for the BMWi's project funding is the Research into the Disposal of Radioactive Waste (2015–2018) funding concept published in February 2015 which, in terms of research policy, is oriented to the content of the Location Selection Act, the National Waste Disposal Programme and the EU Directive 2011/70/Euratom.

Funding aims to create the scientific foundations, develop methods and techniques in line with the art of science and technology and provide knowledge and expertise. This objective is met by applications-oriented, site-independent research and development projects on all host rock relevant to Germany (rock salt, clay and crystalline rock). International collaboration and the promotion of young scientists play an important role here.

By way of supplement to the research and development areas of Final Storage Concepts and Technologies, Nuclear Materials Monitoring and Proof of Safety, the topics of Examining the Effects of Extended Interim Storage Periods on Waste and Containers, Elaboration of Scientific Foundations for the Selection of Sites and socio-technical issues were included in the funding concept as new research and development areas (R&D areas) and the funding of the projects commenced.

In the R&D area of Effects of Extended Interim Storage Periods on Waste and Containers, a collaborative project was approved in 2016 which will be examining the different measurement principles for their suitability for the non-invasive monitoring of the inventory of transport and storage containers for heat-developing waste. Funding amounts to around 1.16 million euros.

In the R&D area of Final Storage Concepts and Technologies, projects will be supported which are intended to answer conceptional, methodological and technical questions using demonstration experiments amongst others. In 2016, five new projects were approved here with funding of around 0.8 million euros. These include projects which deal with the conceptional aspects of final storage in crystalline rock, questions of final storage in deep drill holes and alternative disposal methods. In the R&D area of Proof of Safety, R&D projects are conducted which are intended to provide the basic knowledge necessary for proof of safety. These include experimental work, model theoretical examinations and the further development of the safety analytical instruments. Both the method and the tools to provide proof of safety will be adjusted constantly to the advancing level of science and technology and the requisite data and findings determined. In 2016, 14 new projects (including five joint projects) were approved in this R&D area with funding of some 6.7 million euros.

No new projects were approved in 2016 in the R&D areas of Scientific Foundations of Site Selection and Knowledge Management and Socio-technical Issues. This similarly applies to conceptional, technical and methodological and politico-institutional issues in the R&D area of Nuclear Materials Monitoring. In view of the global significance of the subject, work in this area will be embedded in national and international research networks (Euratom, IAEA).

International cooperation was and is an important component within the R&D activities and is therefore also viewed as an important aspect of funding in the BMWi funding concept. More than one third of all R&D projects funded in 2016 have a direct or indirect reference to international cooperation activities.

Training and further training is another main aspect of funding activities which is also of importance for the maintenance of competence and expertise. 67 young researchers are being funded by the BMWi at the current time as part of ongoing R&D projects.

The subject areas of BMWi project funding are supplemented by BMBF research and development work in nuclear safety research.

In 2016, six collaborative projects with 24 individual projects were funded in the area of disposal research. One new collaborative project (with two individual projects) was approved in 2016 which deals with examining the emission of radio nuclides into the environment and food chain by identifying possible dissemination paths and mechanisms so as to minimise the risks resulting from the emissions on the whole. The project can be assigned to the R&D area of Proof of Safety in the BMWi funding concept.

In 2016, the BMWi funded 96 ongoing projects in the area of disposal research. 21 new projects were supported with funds totalling 8.81 million euros (see Figure 19). In 2016, the BMBF funded research projects with a funding volume of around 1.83 million euros. In this context, the BMBF funded 65 young scientists in 2016.

2.5.3 Radiation research

A focal area of the BMBF funding in nuclear safety research is the area of radiation research.

In the area of radiation research, fourteen joint projects with 65 individual projects were funded on biological, medical and ecological radiation issues. All in all, the BMBF therefore funded approximately 140 young researchers in the area of radiation research in 2016. Research projects in the area of radiation research with funding of around 8.6 million euros were supported in 2016 (see Figure 20).

Figure 19: Funding for nuclear waste final storage and disposal research
(See data in Table 6)

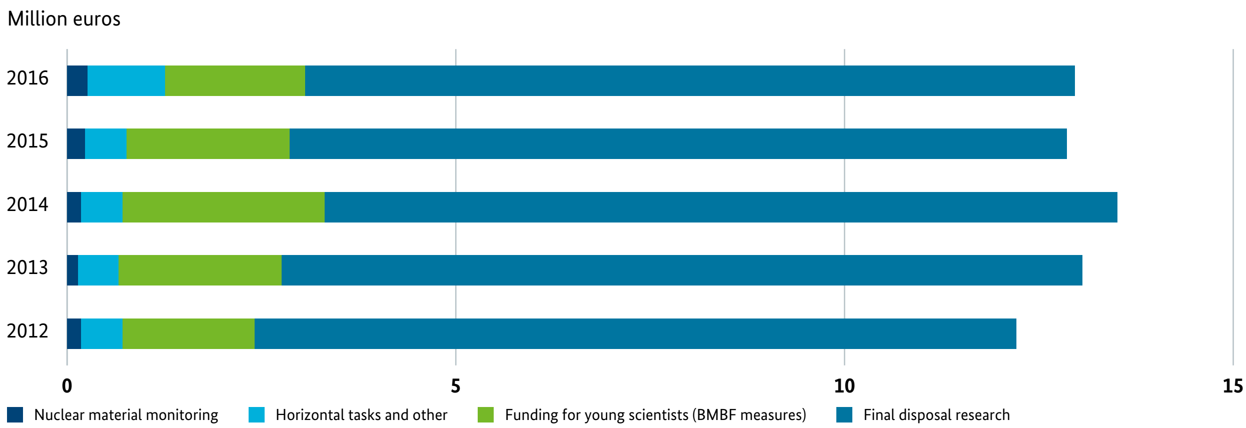
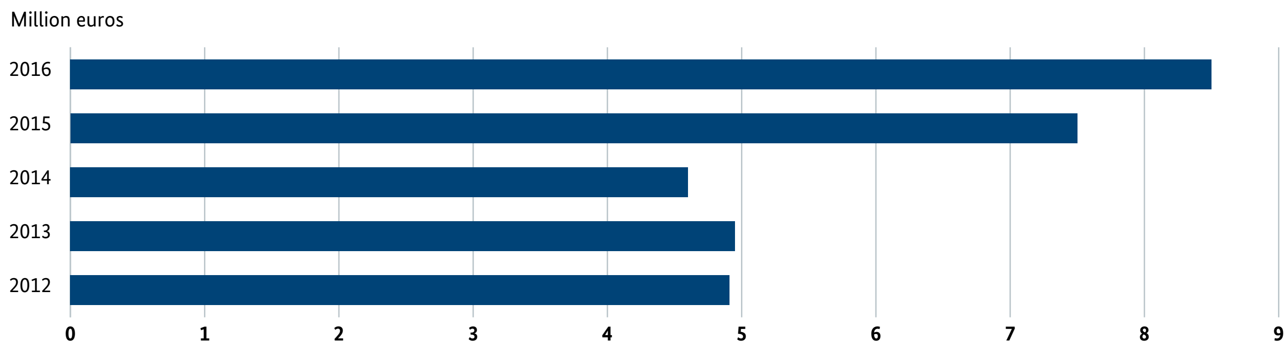


Figure 20: Funding for radiation research
(See data in Table 6)



3. Institutional energy research of the Helmholtz Association of German Research Centres

With over 38,000 employees and an annual budget of over 4 billion euros, the Helmholtz Association of German Research Centres (HGF) is Germany's largest scientific organisation. Specific issues of energy research have been an important element of HGF's research for many years. Since 2015, the start of the third period of programme-oriented funding, the HGF research centres have devoted their attention to energy research in one of a total of six research areas. Due to its size, financial base, the operation of large-scale research equipment and research infrastructures and not least the long-term collaboration between the centres, HGF energy research assumes a special role within the broad research landscape.

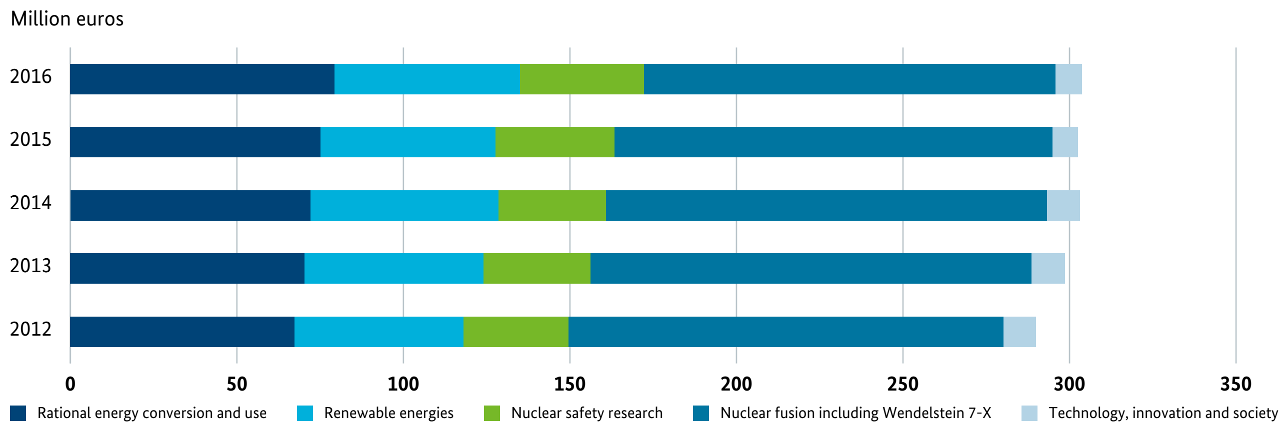
Energy research conducted by the HGF concentrates on issues of basic research which assumes a key role in the necessary technological and economic breakthroughs for the further development of energy technologies. It concentrates on those topics which can best be addressed in the research centres of the HGF due to their complexity, size, need for large-scale equipment and research infrastructures or the necessity of interdisciplinary collaboration. It also addresses preventive research and technological developments which are of relevance to the long-term and very long-term energy supply of Germany, Europe and the world. Finally, research on energy systems is intended to improve the understanding of transformation processes in the conversion of energy supply systems. Energy technologies with specific application perspectives are also researched in the HGF along the entire value added chain where HGF specific research infrastructures exist or where the research area of energy is assigned an outstanding key position with proven unique selling points.

In order to structure the research work and collaboration of the centres, the centres collaborate in seven joint research programmes:

1. Energy efficiency, materials and resources
2. Renewable energies
3. Storage and networked infrastructures
4. Future information technologies (joint programme with the research area of key technologies)
5. Technology, innovation and society (joint programme with the research area of key technologies)
6. Nuclear waste disposal, security and radiation research
7. Nuclear fusion.

The following research centres are involved in the HGF's research area of energy: German Aerospace Centre (DLR), Karlsruhe Institute of Technology (KIT), Forschungszentrum Jülich (FZJ), Helmholtz Centre Berlin for Materials and Energy (HZB), Helmholtz Centre Dresden-Rossendorf (HZDR), Helmholtz Centre Potsdam, German Research Centre for Geosciences (GFZ), Max Planck Institute for Plasma Physics (IPP), Helmholtz Centre for Environmental Research (UFZ).

Figure 21: Topics of the Helmholtz Association of German Research Centres
(See data in Table 7)



At the end of 2015, the scientific council evaluated the procedures and governance structures of the Helmholtz Association and made recommendations on the further development of the programme-oriented funding.[2] These recommendations have direct effects also on the research area of energy. The report of the scientific council was the starting point for basic discussions within the HGF with the aim of making the alignment of the HGF more strategic and effective and strengthening the programme orientation of the procedures in their entirety. One of the suggestions of the scientific council was to introduce a new retrospective quality assessment which is aligned with the joint research programmes of the centres. This retrospective quality assessment in the middle of the funding period is intended to supplement the prospective strategic assessment of programmes at the end of a funding period which in future will be extended to 7 years. The subject matter of discussions last year centered on the shaping and implementation of any such quality assessment based on scientific principles and implemented by international renowned scientists. A decision will be made on the new procedures and governance structures in 2017.

Figure 21 shows the distribution of institutional funding for the HGF research area of energy (federal share only) for 2016 compared with 2012–2015. With the exception of the DLR, funding of the research centres involved was provided from the budget of the BMBF. The DLR is funded by the BMWi budget.

2 See: *"Empfehlungen zur Weiterentwicklung der Programmorientierten Förderung der Helmholtz-Gemeinschaft"* of the scientific council, (WR Publication 4900-15)

4. Other funding activities

4.1 Activities of the Federal Government outside the Energy Research Programme

4.1.1 SINTEG funding programme

Digitalisation is a large influential factor for the development of the energy system in Germany. It is associated with great opportunities such as the expansion of Smart Grids or Smart Homes. Intelligent systems also support a more flexible operation of energy plants and the supply infrastructure, thereby facilitating the integration of fluctuating generation capacities. At the same time, innovative components, information and communication technology, concepts and structures must arise with the assistance of research and development to guarantee a reliable supply.

In SINTEG, the BMWi funds five showcase regions in the research, development and demonstration of innovative applications, structures and concepts for an intelligent energy system of the future. The programme addresses central challenges of the energy transition, such as the system integration of renewable energies, the flexibilisation of the supply system as well as safety and stability. Further focal areas are energy efficiency and the development of intelligent energy grids and market structures.

The showcases were launched in December 2016 and develop and demonstrate scalable sample solutions in large-area model regions. They are then to serve as "blue prints" for a broad implementation throughout Germany. The Ministry supports the project consortiums C/sells, Designetz, enera, NEW 4.0 and WindNODE over a period of four years with a total of over 200 million euros. The companies involved in the projects provide further investments of over 300 million euros. Therefore, over one half of a billion euros goes to digitalisation of the energy sector. This provides important stimulus for the energy transition and for Germany as an innovative location. SINTEG is also part of the BMWi's measures package entitled Innovative Digitalisation of German Industry and is therefore an important stepping stone in the implementation of the Federal Government's digital agenda.

4.1.2 National Hydrogen and Fuel Cell Technology Innovation Programme NIP

A sustainable and low-emission energy supply requires a departure from fossil fuels in the long term. This increases the significance of hydrogen and fuel cell technology. Germany is to become the leading market for sustainable mobility and energy supply. This means not only assuming a knowledge and technology lead by international comparison but also taking on a model role in environmentally compatible transport that goes gentle on resources.

The interdepartmental National Hydrogen and Fuel Cell Technology Innovation Programme (NIP) with a 10-year term has ensured the market preparation of products and applications on the basis of hydrogen and fuel cell technology. From 2007 to 2016, the Federal Government and industry earmarked some 1.4 billion euros for research, development and demonstration projects. The Federal Ministry for Transport and Digital Infrastructure (BMVI) made an important contribution here with 500 million euros.

The NIP is part of the high-tech strategy for Germany and an important element in the long-term implementation of the energy transition in transport. With the market introduction of fuel cells products still in its infancy and the development of a hydrogen infrastructure for transport, the NIP must now be re-aligned. Under the leadership of the BMVI, the Federal Government has established an interdepartmental state programme to continue the NIP up to 2026. The aim here is to make the hydrogen and fuel cell technology competitive in the transport sector by the middle of the next decade and to establish it in the energy market.

The corner stones are presented in the joint Governmental Programme for Hydrogen and Fuel Cell Technology 2016–2026 – from Market Preparation to Competitive Products of the Federal Ministries for Transport and Digital Infrastructure (BMVI), of Economics and Energy (BMWi), for Education and Research (BMBF) and for the Environment, Nature Conservation, Building and Reactor Safety (BMUB).

Projects are funded in the area of hydrogen and fuel cell technologies. As many industrial enterprises, SMEs, users and research institutions as possible are to be involved in the development process. Informative demonstration projects are to provide evidence of the suitability of hydrogen and fuel cell technologies which are already ready for everyday use. The research funds are therefore not only investments in a clean environment but also in future-proof jobs in Germany.

Up to 2019, the BMVI will firstly be providing some 250 million euros to support the hydrogen and fuel cell technology. The BMWi continues its funding of the hydrogen and fuel cell technology in the area of applied research and development as part of the 6th Energy Research Programme with some 25 million euros annually.

4.1.3 EnEff.Gebäude.2050 – Innovative Projects for a Virtually Climate-neutral Building Stock by 2050

The objective formulated in the Federal Government's Energy Efficiency Strategy for Buildings (ESG) in 2015 is for the building stock to be virtually climate-neutral by 2050. The BMWi's funding initiative entitled EnEff.Gebäude.2050 – Innovative Projects for a Virtually Climate-neutral Building Stock by 2050 adopted on 11.04.2016 is intended to make a contribution to achieving this objecitve. Exemplary innovation and transformation projects are to show how the primary energy demand can be reduced with available technologies which have not yet become established on the market and how hurdles can be overcome in the broad-based implementation of virtually climate-neutral buildings. The initiative is intended to link research and broad-scale use more greatly based on existing research results. Furthermore, an ideas competition is to develop concepts for a future international energy competition for buildings and cities which are in the tradition of the Solar Decathlon Europe. The prize money for the competition totals 280,000 euros.

The budget for the new measure is 35 million euros.

4.1.4 Research Campus – Public-Private Partnership for Innovations

The BMBF selectively funds large-scale approaches of location-specific collaboration between science and industry in a long-term binding partnership as part of the hightech strategy in its Research Campus – Public-private Partnership for Innovations funding initiative. Research areas of great complexity with a special potential for leading innovations are addressed in particular. The companies involved receive access to the current level of research and the latest technologies of the respective topic. Universities and research institutions are becoming more attractive for students and companies. Funding is provided in several consecutive phases of up to five years (totalling a maximum of 15 years) with up to two million euros per year. In the energy area, the BMBF supports two research campuses: FEN - Flexible Electric Grids in Aachen and Mobility2Grid in Berlin. The special aspect of the research campus model is the close collaboration between science and industry in a joint campus. The research campus will be continuously further developed for this purpose.

The BMBF has been supporting the FEN – Flexible Electric Grids research campus since 2014 with a total of five projects on the subject of direct voltage grids in the mid-voltage level. In the first of three possible main phases, the BMBF supports the work with a total of ten million euros over a term of five years.

Research is conducted for example on procedures and methods to plan and operate purely direct voltage or hybrid direct/alternating current grids. The development and operation of a medium-voltage direct current research grid on the campus grounds of the Technical University of Aachen (RWTH) is outstanding and an absolute novelty in this form for use in electric energy supply. In addition to the funded projects in the medium-voltage range, FEN also addresses research questions from the low-voltage area in its own consortium. It is also intended to extend collaboration to the high-voltage level. Other focal areas are the development of innovative operating supplies and components, the international standardisation of direct-voltage grids as well as socio-ecological issues.

In the transport sector, the energy transition is decisively based on a comprehensive electrification. The Mobility2Grid research campus conducts research on how the battery capacity of commercial and private electric vehicles can be integrated into decentralised intelligent grids which are based on renewable energies. Both basic technologies and also concepts and business models will be elaborated and tested. For this purpose, Mobility2Grid has set up a "real laboratory" on the EUREF campus in Berlin Schöneberg. The new concepts are researched "live" here with real users and presented publicly.

The BMBF currently supports 23 projects with 9.8 million euros. The first five-year main phase was launched on 1 January 2016. A first highlight is the opening of the ZeeMo.Base, an interactive showroom, which graphically demonstrates both to the potential user and to the interested layman the interaction between electric mobility and Smart Grids on the research campus. The digital networking of the energy system and the enlargement of the electrified vehicle pool on the EUREF campus is making great progress. A self-driving minibus is available, for example, as an innovative test vehicle.

4.1.5 From Material to Innovation

Contributions to energy research are similarly made in the BMBF programme “From Material to Innovation”, for example as part of the Battery 2020 or NanoMatFutur initiatives. Research and development projects were launched on materials and processes for batteries with the application focus placed on electric mobility as part of the Battery 2020 research initiative. The measure also addressed stationary storage. The battery cell production lines existing at different research establishments in Germany were concentrated in the Pro Cell research cluster on battery cell production in order to scientifically flank the manufacturing process of battery cells and its influence on battery cell properties as well as corresponding cost models. A total of 50 million euros has been approved for these measures.

4.2 Research funding from the German states

On behalf of the Federal Ministry for Economics and Energy (BMWi), Project Management Jülich has been conducting an annual analysis of the expenditures from German states on non-nuclear energy research since 2008. In the available survey for 2015, the expenditures from German states for project funding and institutional funding was put at a total of some 267 million euros.

The corresponding expenditures of the Federal Government total some 641 million euros. Total state research funding in the area of non-nuclear energy technologies in 2015 is therefore some 908 million euros. A survey conducted for 2014 showed expenditures of the German states of 256 million euros and Federal Government outlays of 604 million euros. Between the years 2014 and 2015, the nation-wide funding volume in the area of non-nuclear energy research has increased by over 5 percent.

As the main pillar of the national energy research policy, energy savings and efficiency including electric mobility are the funding priority of the German states with a provision of funds totalling 136 million euros in 2015, representing a significant increase by comparison with the previous year (some 118 million euros) (see Figure 22). Further technological differentiation shows that the key technologies of energy storage (28.1 million euros) and power grids (4.3 million euros) were funded to an even greater extent compared with 2014 whilst financial support for electric mobility is declining at a high level at 15.9 million euros.

In the area of regenerative energies, the funding provided is just under 131 million euros, therefore continuing the developments of previous years. Photovoltaics with funding of 24.8 million euros assume the highest position and are funded the most intensively in Baden-Württemberg

Figure 22: Expenditures by the German states for non-nuclear energy research 2008–2015
(See data in Table 9)

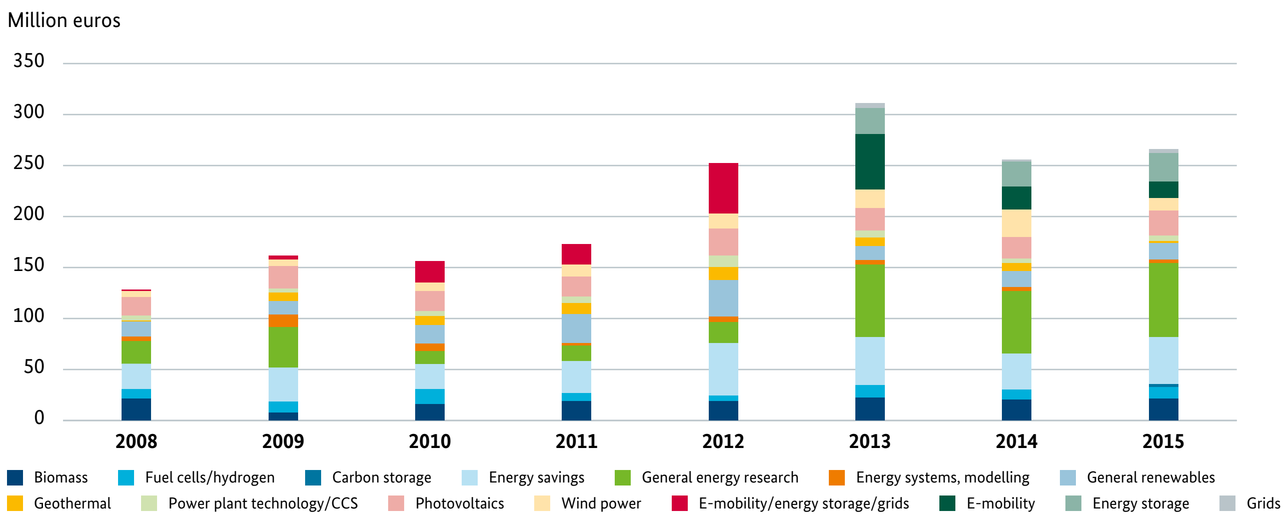
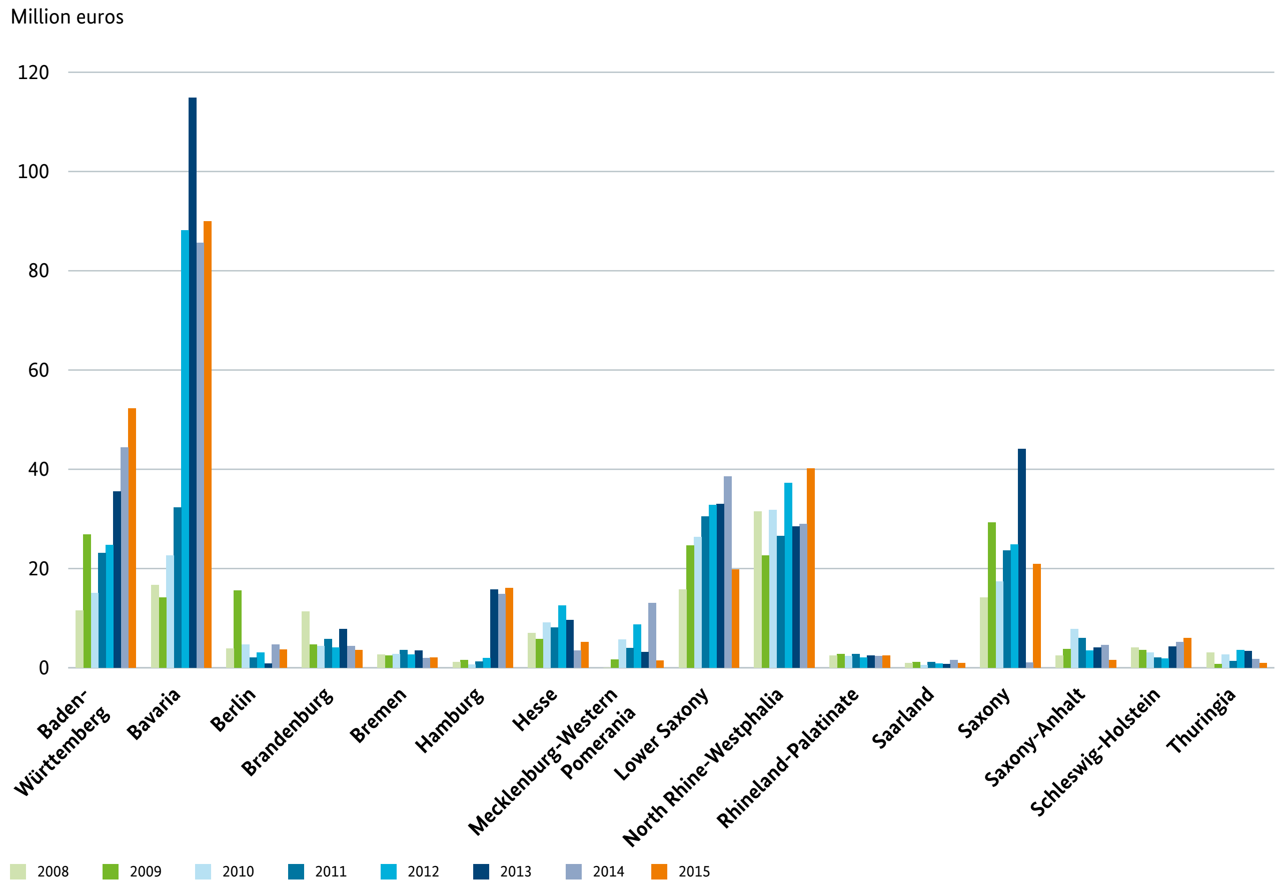


Figure 23: Expenditures for non-nuclear energy research for each German State 2008–2015
(See data in Table 8)



(9.3 million euros), Bavaria (8.1 million euros) and Lower Saxony (2.7 million euros). Biomass research (21.5 million euros) is given the greatest financial support in the German states of Bavaria (8.7 million euros) and North Rhine-Westphalia (6.5 million euros). Wind power research has declined considerably by comparison with the previous year (27.3 to 12.3 million euros) and is now restricted not only to the Northern German states of Lower Saxony (3.6 million euros), Bremen (1.7 million euros), but is also supported in Bavaria (1.8 million euros), Saxony (1.7 million euros) and Baden-Württemberg (1.7 million euros).

With a funding volume of almost 267 million euros, the German states bore some 29% of the total government expenditures in the area of non-nuclear energy research in 2015 and make a considerable contribution to the implementation of the energy transition as well as to the achievement of the associated energy policy targets (see Figure 23).

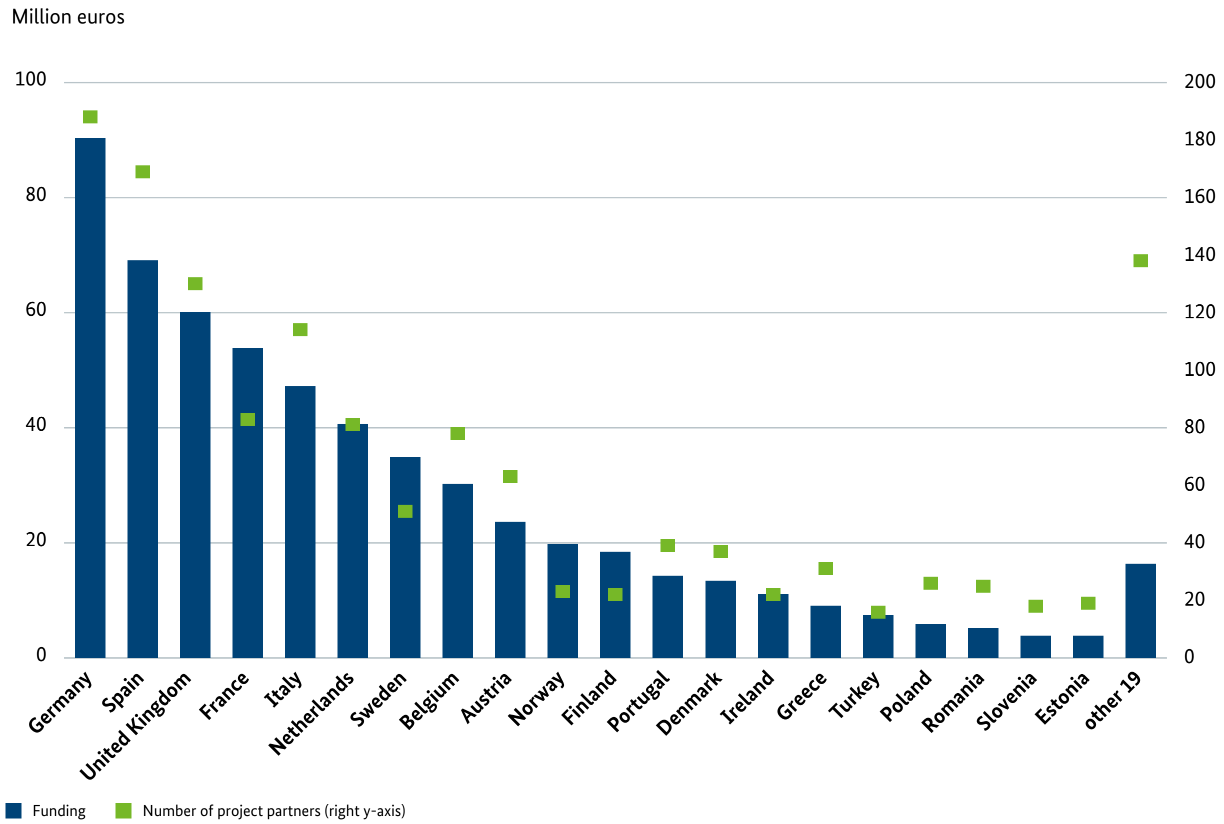
The extensive report entitled Funding of Non-nuclear Energy Research by the German states in 2015 can be obtained from the website of the Project Management Jülich (at https://www.ptj.de/geschaeftsfelder/energie/laenderbericht-energie).

4.3 European Union Framework Programme for Research

Aim and scope of EU research funding

The multi-annual framework programmes for the European Commission's research and technological development have been issued regularly since 1984. They are among the most important instruments for achieving the vision of a European research area. European funding for energy research aims at creating a harmonised European energy system which is sustainable and competitive whilst at the same time guaranteeing a secure energy supply.

Figure 24: Distribution of funding to countries and grant recipients in the area of energy research in Horizon 2020 in 2016 (information from the European Commission for direct project funding[3])



3 The data are not shown in the Table Annex. The data are regularly published in the pertinent publications of the European Commission.

In the subject areas of “secure, clean and efficient energy supply” under Horizon 2020 the European Commission earmarked some 600 million euros for projects from the 2015 calls.

Successful participation of German applicants in the energy area

Applicants from Germany were very successful in the acquisition of projects in 2016. Some 12% of all applicants for funded projects for the social challenge of achieving a “secure, clean and efficient energy supply” came from Germany (see Figure 24). The share of applicants from Germany was particularly high in funded projects in the area of “technologies for renewable energies” (some 24%) and in the subject area of “intelligent cities and municipalities” (some 15%).

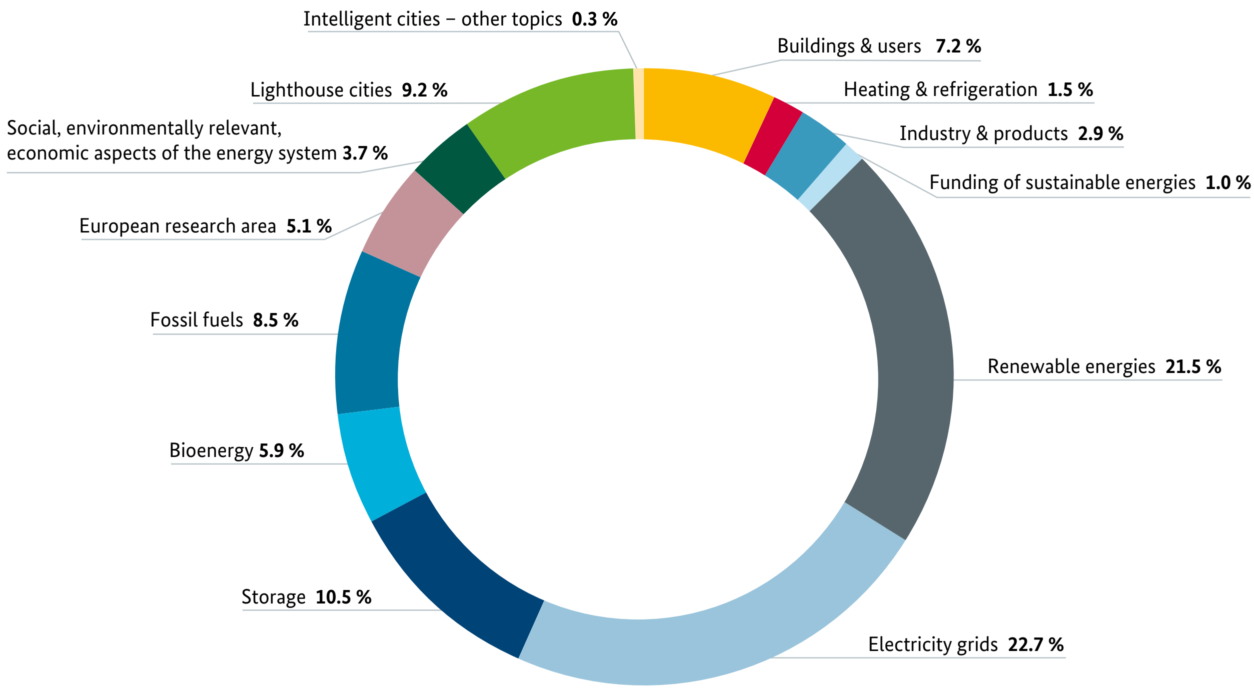
The recipients of funding from Germany are involved in 65 percent of all approved projects with at least one partner and coordinate approximately 20 percent of all projects.

Some 47 percent of grant recipients from Germany come from research institutes and universities. 38 percent come from private companies. The remaining 15 percent of grant recipients are distributed over public and other institutions.

Priorities of energy research

Figure 25 shows the distribution of funding to grant recipients from Germany in accordance with the different energy subjects in the second year of the Horizon 2020 term. The figures show a distinct focus (50 percent) on subjects from the area of renewable energies including bioenergy (together accounting for 27 percent) as well as the subject of electricity grids (23 percent). The subjects of hydrogen and fuel cells are not shown in the figure because they are funded as part of the Joint Technology Initiative for Fuel Cells and Hydrogen – a public-private partnership. There are other energy-relevant funding topics which are assisted in other areas of Horizon 2020, referring, for example, to the building sector, materials research or production technologies.

Figure 25: Distribution of funding in Horizon 2020 in the area of energy research to grant recipients from Germany according to subject areas (2016)



5. Tables

5.1 Funding for the Federal Government's energy research

The following tables on government funding show the sums disbursed in the respective budget years for the individual funding areas. The data were collected in January 2017.

In addition, the number of ongoing (incl. as yet not completed) projects for the reporting year 2016 and the new approved projects are shown as well as the stipulated funding amounts which will be distributed over the subsequent years during the typically multi-year project term.

Table 1 – Overview of topics in the 6th Energy Research Programme of the Federal Government

Funding topic	Disbursements in million euros										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Energy efficiency	110.34	133.95	151.55	189.31	206.13	215.14	239.06	296.64	300.80	317.26	336.09
Renewable energies	120.23	126.47	152.86	202.01	210.61	221.91	258.85	298.10	303.30	323.33	328.82
Nuclear safety and waste disposal	54.33	57.58	62.59	70.41	71.93	73.03	74.74	75.62	76.95	82.92	84.44
Fusion	114.41	121.52	125.58	142.65	131.03	137.44	133.10	138.72	138.14	139.22	126.63
Total	**399.31**	**439.52**	**492.58**	**604.37**	**619.71**	**647.52**	**705.75**	**809.09**	**819.20**	**862.73**	**875.98**

Table 2 – Disbursements of project funding in the area of energy conversion

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Photovoltaics (incl. other programmes)	**67.08** (85.69)	**63.59** (81.16)	**58.34** (64.92)	**71.26** (73.60)	**63.99** (65.66)	**397**	**166**	**116.57**
Crystalline silicon	30.40	30.51	26.72	36.74	36.99	230	106	88.08
Thin-film technologies	15.33	12.69	11.31	10.45	8.78	77	35	18.79
Basic research (incl. other programmes)	15.62 (34.23)	14.87 (32.44)	15.00 (21.59)	11.59 (13.93)	6.17 (7.84)	29	–	–
Other	5.73	5.53	5.31	12.47	12.05	61	25	9.70
Wind Power	**38.42**	**52.57**	**53.06**	**53.04**	**49.69**	**322**	**93**	**86.24**
Wind farm development	2.62	15.07	21.93	25.26	18.40	110	36	53.36
Onshore	0.62	0.51	0.50	1.29	4.10	6	–	–
Offshore	3.34	12.23	12.72	7.98	9.18	65	26	14.26
Wind physics and meteorology	0.12	1.73	2.33	3.62	3.03	29	3	1.89
Logistics, turbine installation, maintenance and operation	23.00	12.88	8.39	6.39	8.10	69	22	14.95
Environmental aspects of wind power and ecological accompanying research	1.43	2.33	2.64	2.46	2.23	21	6	1.78
Other	7.29	7.82	4.54	6.04	4.65	22	–	–

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Table 2 – Disbursements of project funding in the area of energy conversion

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Bioenergy (incl. other programmes)	**40.86** (48.59)	**42.61** (48.68)	**42.97** (44.11)	**42.10** (43.92)	**37.88** (37.88)	**468**	**146**	**30.43**
Production – farming	6.91	6.31	5.98	4.43	4.69	44	32	8.02
Production – cultivation	4.43	5.25	4.77	4.92	4.49	55	7	2.00
Conversion – general	–	–	–	0.53	5.22	43	41	9.52
Conversion – gaseous	4.61	4.87	5.27	6.84	4.92	53	–	–
Conversion – liquid	4.11	6.12	6.19	5.92	3.97	31	–	–
Conversion – solid	2.78	0.94	0.73	1.92	2.23	36	13	2.18
Cross cutting research	1.86	3.22	2.85	2.97	2.53	44	16	2.73
Basic research (incl. other programmes)	8.81 (16.53)	9.99 (16.06)	12.16 (13.30)	9.89 (11.72)	6.17 (6.17)	62	–	–
Use of biomass for energy	7.36	5.91	5.03	4.69	3.66	100	37	5.98
Deep geothermal energy	**20.82**	**17.10**	**15.55**	**13.38**	**12.54**	**83**	**22**	**19.55**
Surveying and exploration	8.39	7.28	9.13	9.12	6.67	44	5	7.31
Hot water and steam deposits	4.36	4.97	3.03	2.59	4.61	14	5	4.78
Hot dry rock	3.69	0.91	0.33	0.45	1.02	21	12	7.46
Other	4.37	3.94	3.05	1.22	0.23	4	–	–
Power plant technology and CCS technologies (incl. other programmes)	**27.54** (28.58)	**31.62** (35.09)	**29.60** (30.96)	**28.20** (28.20)	**28.52** (28.52)	**312**	**73**	**29.03**
Advanced power plant systems	10.76	7.45	6.36	2.41	4.84	41	15	4.93
Component development	9.18	16.52	18.19	19.19	17.53	247	58	24.10
Coal gasification	2.39	1.54	1.46	2.80	3.52	10	–	–
Basic research (incl. other programmes)	4.54 (5.58)	3.79 (7.27)	2.86 (4.22)	1.97 (1.97)	1.36 (1.36)	–	–	–
Other	0.68	2.32	0.74	1.82	1.27	14	–	–
Fuel cells and hydrogen	**19.47**	**24.88**	**27.16**	**22.32**	**19.69**	**147**	**28**	**18.48**
LT-PEMFC	6.15	6.68	9.92	6.43	4.42	52	17	8.38
HT-PEMFC	1.30	1.75	1.21	1.01	0.77	5	–	–
MCFC	0.55	0.14	0.30	1.64	0.82	4	2	0.35
SOFC	7.40	11.10	7.84	6.53	4.27	29	9	9.74
DMFC	0.56	0.34	0.06	–	–	–	–	–
Hydrogen storage	1.98	3.16	2.25	2.36	0.99	9	–	–
Hydrogen production	0.83	0.63	0.30	0.59	2.14	14	–	–

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Table 2 – Disbursements of project funding in the area of energy conversion

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Basic research	0.71	1.08	3.04	2.10	4.28	21	–	–
Other	–	–	2.23	1.67	2.01	13	–	–
Solar thermal power plants	**7.45**	**8.41**	**9.25**	**10.09**	**8.58**	**76**	**13**	**8.90**
Parabolic	3.67	2.25	1.84	0.74	2.04	25	5	4.86
Tower	2.01	2.50	3.59	4.23	2.86	30	8	4.04
Fresnel	0.68	0.63	0.82	–	–	–	–	–
Storage	0.30	1.79	1.41	1.85	1.37	5	–	–
Other	0.78	1.24	1.59	3.28	2.32	16	–	–
Hydroelectric and marine power	**0.98**	**1.25**	**1.21**	**1.68**	**2.01**	**17**	**4**	**3.51**
Total (incl. other programmes)	**222.62** (249.99)	**242.02** (269.15)	**237.14** (246.23)	**242.06** (246.22)	**222.90** (224.57)	**1822**	**545**	**312.72**

Table 3 – Disbursements of project funding in the area of energy distribution and energy use

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Energy storage (incl. other programmes)	**31.02** (38.90)	**59.30** (61.46)	**56.99** (57.26)	**61.59** (61.76)	**53.00** (53.00)	**395**	**109**	**56.98**
Electrochemical storage	14.48	23.87	19.86	18.41	21.24	131	63	29.89
High temperature storage	0.47	0.47	1.52	3.51	2.16	22	–	–
Mechanical storage	1.19	3.26	1.53	1.97	2.48	22	11	6.15
Electrical storage	0.74	0.28	0.05	2.48	4.54	36	1	0.05
Low temperature storage	1.53	3.37	5.13	5.14	3.19	36	–	–
Basic research (incl. other programmes)	10.20 (18.08)	19.37 (21.53)	17.21 (17.48)	15.61 (15.77)	10.79 (10.79)	64	–	–
Other	2.41	8.67	11.70	14.48	8.61	84	34	20.90
Power grids	**16.74**	**30.95**	**34.88**	**52.85**	**70.93**	**620**	**119**	**53.23**
Components	1.93	10.15	12.12	13.60	17.87	145	56	29.69
Grid planning	0.78	2.51	3.24	4.00	4.26	49	–	–
System management	9.74	12.62	10.40	18.72	27.98	261	57	19.69
System studies	0.06	1.68	3.60	2.94	1.90	18	3	2.02
Basic research	3.06	0.49	1.26	9.46	14.02	93	–	–
Other	1.17	3.50	4.26	4.12	4.90	54	3	1.83

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Table 3 – Disbursements of project funding in the area of energy distribution and energy use

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Energy efficiency in buildings and cities	**45.81**	**56.76**	**60.55**	**54.86**	**53.60**	**549**	**148**	**69.19**
(incl. other programmes)	(47.74)	(58.94)	(63.53)	(54.86)	(53.72)			
EnOB – Solar-optimised building	19.65	25.50	30.95	30.86	26.33	283	75	31.91
EnEff:Stadt – Supply concepts	7.85	9.69	9.28	9.06	11.62	106	40	19.29
EnEff:Stadt – District heating	2.50	3.53	3.75	2.87	3.16	37	7	3.87
EnEff:Stadt – Combined heat and power	2.93	4.61	2.65	1.39	0.89	13	2	1.21
Low-temperature solar thermal energy	4.90	6.47	6.36	5.54	6.43	83	24	12.90
Solar cooling	1.73	1.21	1.02	0.48	0.13	–	–	–
Basic research (Energy-efficient Cities Competition)	3.63	4.49	5.36	4.65	3.88	18	–	–
(incl. other programmes)	(3.63)	(4.49)	(5.36)	(4.65)	(4.00)			
BMUM Future of Buildings research initiative (other programme)	(1.93)	(2.18)	(2.98)	–	–			
Other	2.62	1.25	1.19	–	1.17	9	–	–
Energy efficiency in industry, commerce, trade and services	**30.01**	**36.38**	**34.70**	**34.85**	**33.70**	**379**	**115**	**56.57**
Mechanical, automotive, electrical and precision engineering, optics, metal goods	10.90	14.97	16.07	14.30	9.57	104	29	19.75
Iron and steel industry	2.42	1.54	0.69	0.67	0.55	14	3	1.20
Mining and processing of stone and earth, fine ceramics, glass	2.05	2.41	1.45	0.54	1.20	15	10	5.48
Heat pumping, refrigerants	1.28	2.99	2.58	3.02	3.83	23	–	–
Industrial furnaces	1.19	0.83	0.67	0.99	1.41	35	18	6.80
Mechanical and thermal separation methods	0.39	1.57	1.79	2.23	2.05	33	18	5.54
Chemical industry, manufacturing of plastic and rubber products	1.52	2.79	4.05	4.81	5.46	57	14	8.68
Non-ferrous metal industry	0.44	0.56	0.72	0.79	1.09	14	–	–
Heat exchangers	2.11	1.82	1.13	1.61	1.46	10	–	–
Solar process heat	0.35	0.25	0.10	0.10	0.09	1	–	–

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Table 3 – Disbursements of project funding in the area of energy distribution and energy use

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Basic research	–	–	1.76	0.79	0.32	1	–	–
Other	7.35	6.64	3.68	5.01	6.68	72	23	9.13
Total (incl. other programmes)	**123.57** (133.38)	**183.39** (187.72)	**187.11** (190.36)	**204.14** (204.31)	**211.24** (211.36)	**1943**	**491**	**235.97**

Table 4 – Disbursements in system-oriented project funding including horizontal subjects

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Horizontal issues and system analysis	**8.60**	**11.70**	**10.82**	**11.46**	**13.67**	**147**	**67**	**27.00**
System analysis	1.57	2.38	3.03	3.75	7.42	108	65	26.78
Information dissemination	2.49	3.27	3.33	4.09	3.74	10	–	–
Horizontal issues	4.10	5.38	4.13	3.35	2.42	29	2	0.21
Other	0.44	0.66	0.33	0.27	0.09	–	–	–
Total	**8.60**	**11.70**	**10.82**	**11.46**	**13.67**	**147**	**67**	**27.00**

Table 5 – Disbursements of other project funding BMBF

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Socio-ecological research (incl. other programs)	**–** –	**1.18** (3.08)	**3.25** (8.58)	**3.95** (11.11)	**2.64** (4.42)	**36**	–	–
Energy materials	–	–	**0.72**	**10.41**	**27.87**	**144**	**29**	**19.96**
Copernicus projects	–	–	–	–	**0.40**	**158**	**158**	**115.60**
Carbon2Chem	–	–	–	–	**8.64**	**26**	**26**	**49.05**
Project-related fusion research	**2.58**	**6.29**	**5.55**	**7.70**	**3.12**	**3**	–	–
Other BMBF project funding (incl. other programmes)	**7.11** (7.11)	**2.35** (3.23)	**3.93** (3.93)	**3.23**	**4.19**	**15**	**1**	**9.76**
Other (incl. other programmes)	**9.69** (9.69)	**9.82** (12.61)	**13.45** (18.79)	**25.29** (29.22)	**46.86** (44.44)	**382**	**214**	**194.38**

Table 6 – Disbursements in the area of nuclear safety research

Funding area	Disbursements in million euros					Number of projects		Funding total in million euros
	2012	2013	2014	2015	2016	ongoing in 2016	new in 2016	approved in 2016
Nuclear waste final storage and disposaal research	**12.30**	**13.23**	**13.58**	**12.95**	**13.09**	**120**	**24**	**11.10**
Final storage research	9.84	10.39	10.25	10.06	9.94	88	18	7.47
Horizontal issues and other	0.54	0.53	0.53	0.54	1.06	7	3	1.34
Nuclear material monitoring	0.18	0.15	0.19	0.24	0.26	1	–	–
Funding for young researchers (BMBF measures)	1.74	2.17	2.61	2.11	1.83	24	3	2.29
Reactor safety research	**24.38**	**23.43**	**25.10**	**25.22**	**24.06**	**164**	**27**	**17.24**
Safety of nuclear facility components	5.28	4.01	4.38	4.55	4.38	41	10	2.84
Plant behaviour and accident sequences	11.25	12.09	12.51	13.22	13.37	74	15	13.61
Horizontal tasks and other	5.08	5.72	4.81	4.05	3.63	22	2	0.78
Funding for young researchers (BMBF measures)	2.77	1.62	3.39	3.39	2.68	27	–	–
Radiation research – funding for young researchers (BMBF measures)	**4.91**	**4.95**	**4.61**	**7.58**	**8.58**	**65**	**–**	**–**
Total	**41.59**	**41.61**	**43.29**	**45.74**	**45.73**	**349**	**51**	**28.34**

Table 7 – Disbursements in institutional energy research

Funding area	Disbursements in million euros				
	2012	2013	2014	2015	2016
Rational energy conversion and use	67.34	70.34	72.09	75.08	79.34
Renewable energies	50.75	53.74	56.52	52.46	55.59
Nuclear safety research	31.64	32.22	32.26	35.76	37.27
Nuclear fusion including Wendelstein 7-X	130.52	132.43	132.59	131.52	123.51
Technology, innovation and society	9.92	10.05	9.95	7.75	8.07
Total	**290.17**	**298.78**	**303.41**	**302.57**	**303.78**

5.2 Funding for energy research from German states

The information is based on notifications from the German states from a survey regularly commissioned by the BMWi. In the case of funding from the European Regional Development Fund (ERDF), only the part assumed by the German states is taken into consideration. No figures are as yet available for 2016.

Table 8 – Expenditures of the German States for non-nuclear energy research

German state	Disbursements in million euros							
	2008	2009	2010	2011	2012	2013	2014	2015
Baden-Württemberg	11.54	26.83	15.10	23.12	24.77	35.55	44.37	52.22
Bavaria	16.67	14.14	22.64	32.28	88.13	114.82	85.61	89.98
Berlin	3.87	15.53	4.73	2.10	3.03	0.88	4.70	3.63
Brandenburg	11.34	4.65	4.37	5.81	4.03	7.86	4.40	3.54
Bremen	2.71	2.42	2.78	3.61	2.71	3.46	1.99	2.08
Hamburg	1.15	1.56	0.61	1.27	2.01	15.76	14.91	16.12
Hesse	7.02	5.77	9.10	8.12	12.57	9.63	3.48	5.17
Mecklenburg-Western Pomerania	–	1.64	5.68	3.99	8.76	3.22	13.02	1.50
Lower Saxony	15.74	24.60	26.36	30.53	32.82	33.00	38.57	19.78
North Rhine-Westphalia	31.52	22.68	31.80	26.55	37.27	28.52	28.99	40.14
Rhineland-Palatinate	2.43	2.76	2.40	2.79	2.10	2.43	2.37	2.51
Saarland	0.95	1.17	0.51	1.12	0.87	0.75	1.56	0.98
Saxony	14.18	29.26	17.42	23.60	24.88	44.06	1.01	20.89
Saxony-Anhalt	2.51	3.83	7.81	6.04	3.43	4.11	4.62	1.53
Schleswig-Holstein	4.12	3.54	3.10	2.08	1.83	4.28	5.15	5.97
Thuringia	3.10	0.78	2.68	1.36	3.55	3.40	1.81	0.95
Total	**128.87**	**161.14**	**157.11**	**174.39**	**252.78**	**311.74**	**256.56**	**266.99**

Table 9 – Expenditures of the German states for non-nuclear energy research by sector

Sector	Disbursements in million euros							
	2008	2009	2010	2011	2012	2013	2014	2015
Biomass	21.48	7.79	15.90	18.73	18.71	22.44	20.56	21.53
Fuel cells and hydrogen	9.47	10.86	15.14	8.11	5.40	12.29	9.82	11.46
Carbon storage	–	0.11	0.24	0.07	0.21	–	0.02	2.77
Energy saving	24.86	32.19	23.74	31.66	51.35	45.58	34.73	46.10
General energy research	22.21	40.20	12.97	14.96	21.01	72.81	61.73	73.03
Energy systems, modelling	4.48	12.02	7.87	2.46	5.37	4.53	4.33	3.13
Renewables, general	14.45	13.38	18.09	28.28	35.83	13.50	15.34	15.96
Geothermal	1.27	8.41	8.86	11.27	12.52	8.43	8.09	2.09
Power plant technology/ CCS	5.09	3.87	4.84	6.09	11.35	7.12	4.25	5.52
Photovoltaics	18.12	22.17	19.62	20.84	26.95	21.85	21.31	24.81
Wind power	5.89	6.12	8.26	11.61	14.48	18.60	27.29	12.25
E-mobility / power storage / grids	1.55	4.02	21.58	20.31	49.61			
E-mobility						54.19	22.54	15.88
Energy storage						25.84	24.16	28.12
Grids						4.58	2.40	4.33
Total	**128.87**	**161.14**	**157.11**	**174.39**	**252.78**	**311.74**	**256.56**	**266.99**

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