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Energiewende
Switch to the Future

Report of the Federal Government on Energy Research 2014

Research Funding for the Energiewende

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Federal Ministry for Economic Affairs and Energy (BMWi)
Public Relations
E-Mail: publikationen@bundesregierung.de
www.bmwi.de

Central procurement service:
Tel.: +49 30 182722721
Fax: +49 30 18102722721

Table of Contents

1. Research Funding for the Energiewende

In September 2010, the German government laid out the plan for the medium to long-term energy supply in Germany with its Energy Concept. After the earthquake disaster in Japan in March 2011 and the resulting flooding of the Fukushima Nuclear Power Plant, the German government re-assessed the role of nuclear power and set the maximum lifespan of the plants in Germany at 32 years. The last nuclear power plant is to be shut off at the end of 2022 at the latest. In relation to the Energy Concept, the early phase-out of nuclear energy should be compensated by a quicker implementation of the planned measures. This reorientation of the energy supply in Germany, known as the "Energiewende," has attracted worldwide attention. It is primarily based on the halving of primary energy consumption by 2050 and the expansion of renewable energies to an amount of 60 percent of gross final energy consumption. Because the currently available energy technologies are not sufficient to realise these ambitious goals while preserving security of supply and the level of prosperity, the German government is supporting research and development in companies, universities and research institutions.

By promoting research in the field of energy technologies, the government aims to meet its energy requirements and climate policy commitments. In economic terms, the leading position of German companies will also be increased in the field of modern energy technologies. Since, the development of world markets is characterised by a growing demand for energy in emerging and developing countries. This opens up a wide range of possibilities for German companies with positive effects on growth and employment. In addition, the use of advanced energy technologies supports international climate protection efforts through the successive use of more efficient and low carbon energy systems. Last but not least, energy research increases the range of technical options for energy conversion and utilisation, and contributes to security of supply. This creates the room to manoeuvre to be able to adapt the energy supply to changes in energy market conditions.

The current report is an update of the "Report of the Federal Government on Energy Research 2013"[1] published last year and provides an updated overview of the structure and main areas of energy research funded by the German government. It focuses on project funding and summarises institutional funding as well. Since the German states and the European Commission financially support diverse research, this edition of the Report of the Federal Government on Energy Research will also discuss these research priorities. Thereby, this report improves the transparency of research funding and thus contributes to the objectives of the German government's Sixth Energy Research Programme entitled "Research for an environmentally sound, reliable and affordable energy supply."

Development of Funding

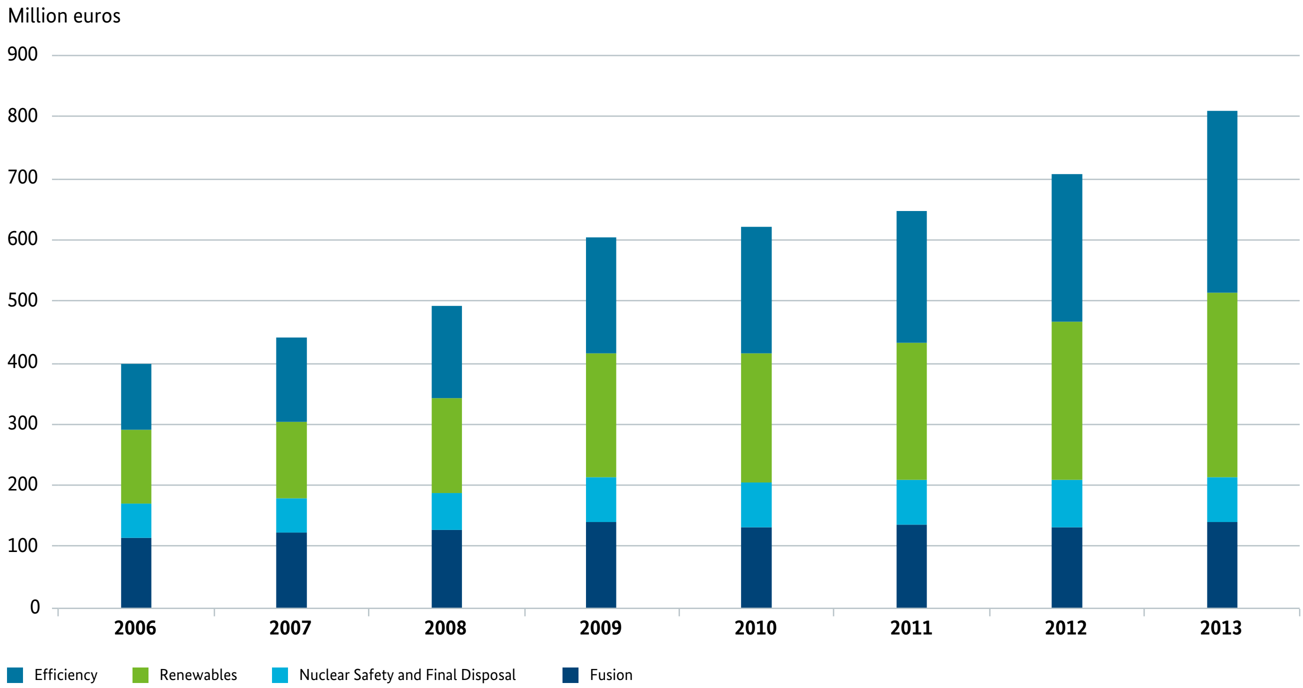
The increase of resources in the Energy Research Programme (see overview in Fig. 1) from 399 million euros (2006) to 705 million euros (2012) was able to continue to grow strongly in the reporting year by 14.6 percent, so that it reached a total of 809 million euros in the 2013 budget year. These numbers include 168 million euros from the Energy and Climate Fund starting in 2011.

In accordance with the objectives of the Sixth Energy Research Programme, the two areas that have been particularly strengthened are energy efficiency and renewable energies: with 297 million euros for energy efficiency and 298 million for renewable energy sources, approx. 74 percent of the resources flowed into these areas which are of particular importance for the Energiewende.

Project funding has emerged as a tool particularly suited to respond flexibly to research dynamics and to provide effective support. While the ratio of project funding to the overall budget was 49 percent in 2006, 63 percent of the funds were already implemented in 2013 in joint projects and single projects that were applied for individually.

1 Available in German only.

Figure 1: Overview of the Topics in the German Energy Research Programme, actual outlays
(See data in Table 1)



1.1 New Structures in Energy Research

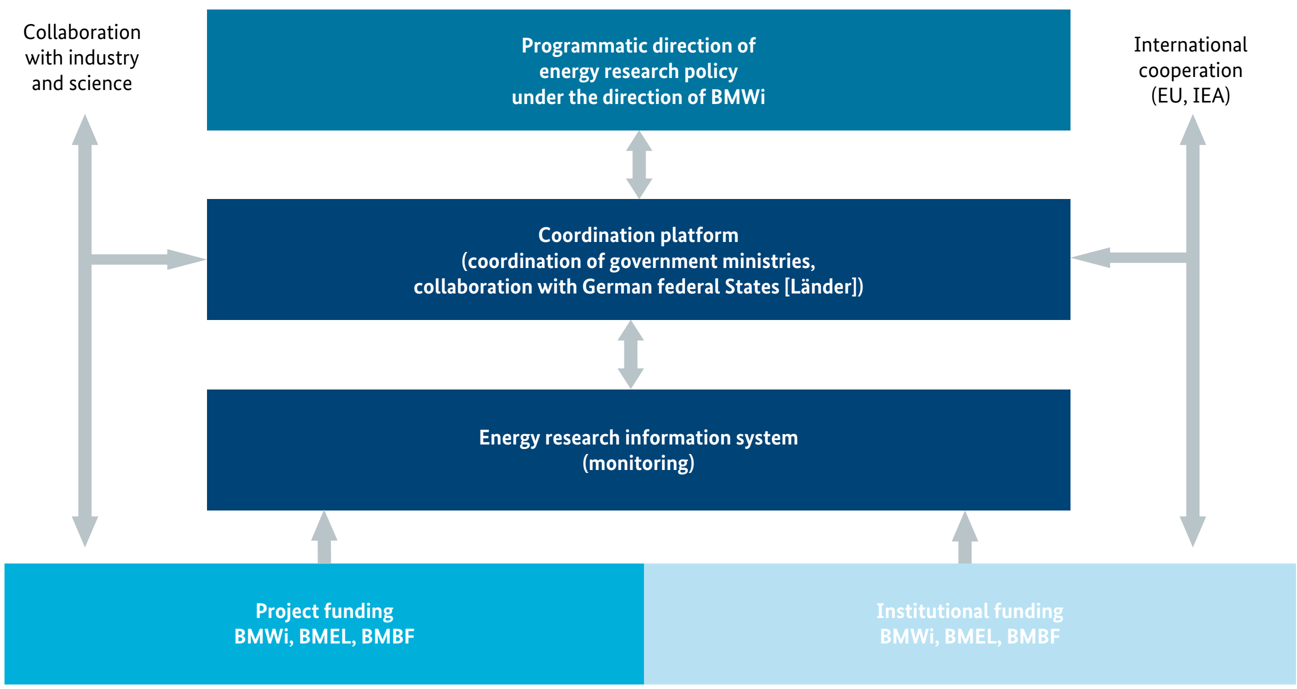
Announced in the coalition agreement on the November 11, 2013, the German government decided to resolutely focus energy research on the Energiewende. At the core of this are intelligent solutions in the areas of energy efficiency, energy conservation, renewable energy and supply systems (including storage, grids and ancillary system services through renewable energy). Furthermore, new, thematically comprehensive and system-oriented research approaches are to be initiated within the framework of the project funding. The European dimension will be taken into consideration by the appropriate cross-linking of research activities.

At the ministerial-administrative level, the German government is strengthening the importance of energy policy by tailoring a new ministry. German Chancellor Angela Merkel issued an organisational directive on December 17, 2013 that transferred the responsibilities for the Energiewende from the Federal Transport and Federal Environment Ministries to the Federal Ministry of Economics under the new name, Federal Ministry for Economic Affairs and Energy.

This also had an impact on the organisation of energy research. Thus, the responsibility for application-oriented research in the areas of energy efficiency and renewable energy now rests with the Federal Ministry for Economic Affairs and Energy (BMWi). However, the Federal Ministry of Education and Research (BMBF) still coordinates the funding of basic research in the field of energy technology and the Federal Ministry of Food and Agriculture (BMEL) of applied research in bioenergy.

The control over the government's programmatic orientation rests with the BMWi, although the inter-ministerial and international cooperation is done within the framework of the Coordination Platform Energy Research (see structure in Fig. 2). The information system Energy Research depicts project funding and institutional support in a transparent manner. A regular exchange of information between industry and academia – both nationally and internationally – ensures the practical relevance and takes the current technical and scientific developments into account.

Figure 2: Organisation of the Energy Research by the German Government



1.2 Development of the Sixth Energy Research Programme

The German government formulates its energy research policy in its regularly updated Energy Research Programme. The current Sixth Energy Research Programme is aligned to the objectives of the Energiewende. The government is convinced that this reliable framework will promote effective and efficient research. This requires a long-term research policy. Therefore, the participants of the Coordination Platform for Energy Research decided to use the opportunity of the new ministry layout to continue to develop the Sixth Energy Research Programme. This is oriented towards four guidelines:

- Strategic strengthening of thematically comprehensive and system-oriented approaches to research in areas of particular relevance for the Energiewende
- Further development of European networking through research collaborations in particular on issues with a clear European dimension
- Continued strengthening of the coordination and cooperation with the German states
- Transparency in regards to energy research activities by implementing a modern information system

Participating Departments

Compared to the first version of the Sixth Energy Research Programme, the organisational decree assigns all activities that were initially the responsibility of the Federal Environment Ministry to the Federal Ministry for Economic Affairs and Energy. This results in the following situation for the organisation of research funding in the Energy Research Programme:

- The BMWi is responsible for the programmatic orientation and coordination of the German government's Energy Research Programme. Thematically, the BMWi is entrusted with application-oriented project funding in the areas of energy efficiency, renewable energy sources and nuclear safety and waste disposal research, as well as for institutional funding in the field of energy at the German Aerospace Center (DLR) in the Helmholtz Association of German Research Centres (HGF).

- The BMEL is responsible for supporting application-oriented project funding in the field of bioenergy.

- The BMBF is responsible for the basic research project funding for Energy Research and for the institutional funding for the HGF centres (with the exception of the DLR), the Fraunhofer Society, the Max Planck Society and the Leibniz Association.

- The BMBF's basic research forms the basis for the optimisation of existing methods and the discovery of future innovations. It covers emerging technologies and anticipatory research. The application-oriented research of the BMWi and the BMEL funds research, development and demonstration of possible future applications and thus creates the conditions for the implementation of innovations.

Within the *National Hydrogen and Fuel Cell Technology Innovation Programme (NIP)*, the Federal Ministry of Transport and Digital Infrastructure (BMVI) funds – in addition to the funding presented here for technological development by the BMWi in the Sixth Energy Research Programme – market preparation activities such as demonstration and infrastructure projects and field tests in the context of applied research and development.

Research Topics

The Sixth Energy Research Programme defines the basic orientation of the research topics. The measures are continuously expanded taking the above-mentioned new responsibilities into consideration. The respective departments are – if necessary – publishing the adjustments and additional information about specific funding opportunities as well as calls for proposals.

The Sixth Energy Research Programme sowed the seeds for increased system-oriented research approaches with the element of the interdepartmental research initiatives. Taking into consideration the new guidelines, the funding of research in the fields of energy storage and future-oriented power grids is being continued and expanded.

With the merging of project funding for the applied research of non-nuclear energy technologies (with the exception of bioenergy) in the BMWi, synergy effects are arising between the closely related funding areas that were previously spread across two ministries. This has the effect of simplifying communication and accelerating coordination:

- Research into low-temperature solar thermal energy is closely related to projects on energy efficiency in the building sector, energy-optimised construction and energy-efficient cities. Therefore, the individual research initiatives will be structurally bundled into a research platform for energy efficient cities and buildings.

- Research projects on energy storage and grid technologies generally have similar relations to energy efficiency (previously BMWi) and renewable energies (previously BMU). Now, these projects are housed in one ministry.

- Cross-system approaches are of particular importance for the successful implementation of the Energiewende. The design and the various aspects of environmentally friendly, reliable and affordable energy supplies for the future require analytical views of the overall system, the development of possible ways of optimising it and special attention to the integration of renewable energies. Research work in this overarching topic area will become even more important in future.

Interdepartmental Research Initiatives

Technical energy systems, like power grids and district heating networks as well as technical building equipment and systems, are characterised by high levels of investment and long service lives. Adjustment processes therefore require long periods of time, because they usually focus on renovation and replacement intervals. Nevertheless, it is becoming clear that the implementation of the Energiewende also requires major changes to the energy supply structure, which necessitates the use of new technical solutions. Thus, the energy supply in Germany will be characterised by greater flexibility and increasing integration of previously separated supply areas. An increasing share of fluctuating electricity supply, a strong decentralisation as well as an increase in the transport of electricity over long distances go hand in hand with the expansion of renewable energy.

Against this backdrop, the departments participating in the Energy Research Programme launched joint funding initiatives, in which important cross-platform technologies are being developed and tested.

In 2011, the interdepartmental “Energy Storage Research Initiative” (“Forschungsinitiative Energiespeicher”) was brought into being (see Chapter 2.2.1). For example, this initiative covers projects investigating the coupling of wind power with hydrogen and methane production and projects investigating the operation of batteries in distribution grids. Additionally, there are also a variety of individual technological developments as well as systems analysis studies on the potential applications of energy storage in conjunction with existing energy supply structures.

In the interdepartmental research initiative “Future-proof Power Grids” (“Zukunftsfähige Stromnetze”) advertised in 2012 (see Chapter 2.2.2), the expansion of power grid infrastructure and its focus on feeding in larger amounts of renewable energy into transmission and distribution girds is to be promoted. The initiative is funding development of procedures, equipment as well as safety, monitoring and communication techniques for the intelligent and automated operation of distribution grids. New transmission technologies, such as high voltage direct current (HVDC), and their integration into the existing three-phase network, as well as questions of planning, acceptance and the structural design of the power line system are at the centre of the transmission grids research area.

1.3 European Networking

SET-Plan and the Berlin Model

With the SET-Plan (Strategic Energy Technology Plan), the European Union has adopted a European energy strategy that should lead to a low carbon yet competitive and affordable energy system in Europe as soon as possible. To implement this goal, the industry has been called upon to play a leading role. In so-called industry initiatives, industry partners are compiling so-called *Implementation Plans* with the support of EU and European Commission members and associated states. The plans will strengthen industry participation in energy research and demonstration projects, stimulate innovation and develop low carbon energy technologies. So far, European Industrial Initiatives (EII) have officially started work in the following areas: Wind, photovoltaic and concentrated solar power plants, bioenergy, fuel cells and hydrogen (as a so-called Joint Undertaking, see Chapter 4.2), carbon capture and storage (CCS), power grids, smart cities, nuclear power and fusion.

As an additional body, the European Energy Research Alliance (EERA) is supporting the implementation of the SET-Plan. Leading European research institutes have taken on the goal of strengthening research efforts for the necessary energy technologies of future energy systems through joint projects. The combination of national and EU research funding and the benefits of synergies and complementarities effectively pool together the activities and resources to meet the objectives of the SET-Plan in the EERA.

Energy research in Germany will increasingly support research on a European scale in the future because the success of the SET-Plan will depend largely on its integration into national funding strategies and programs. Because the financial support for the research and innovation necessary for the SET-Plan road map and implementation plan cannot be funded from European Commission programs alone, international cooperations with various financial funding approaches will be of increasing importance in the future:

For the implementation of the SET-Plan, Germany has proposed the “Berlin Model.” The core element of this funding model is an as unbureaucratic and efficient multinational funding for research projects as possible in close cooperation with the respective national funding programs or organisations. The first bilateral collaborative projects using this model were successfully started as part of a joint call for proposals with Finland on the topic of energy efficiency in 2013. Other cooperations exist with Austria and Switzerland in research areas which focus on energy efficient cities and hydrogen and fuel cell technology. There are plans for an expansion of funding based on the Berlin Model.

Horizon 2020

In the European context of energy research, the “Horizon 2020” programme replaced the European Union’s previous “Seventh Framework Programme for Research and Technical Development” (FP7) in 2014. As one of seven “social challenges”, the area of “secure, clean and efficient energy” dictates which funding can be made available for non-nuclear energy research. Beyond these areas, as another part of Horizon 2020, research activities in the areas of nuclear fission and radiation protection as well as fusion research will be funded under the program of the European Atomic Energy Community (Euratom). Chapter 4.2 explains further details about non-nuclear topics and takes a look at the previous FP7.

1.4 National Networking

The Energiewende is a task for society as a whole and requires the inclusion of all parties involved in politics, business, science and society. Many aspects must be aligned in the future energy system: technical feasibility, economical implementation, environmental impact, social acceptance and energy policy. For a start, this complexity can be managed only with strong research. Moreover, there must be a constant transfer of knowledge, experiences and expectations between all of the parties involved.

The BMWi, as the leading department, has set up the Coordination Platform for Energy Research for this information exchange (see Fig. 2) with the participation of the federal ministries BMBF, BMWi and BMEL, which were in charge of the Sixth Energy Research Programme. In this platform – taking into account the growing importance of the European aspects – the cornerstones for governmental funding for research in the field of energy are established and interdepartmental cooperation is arranged.

A strategic research agenda in the field of basic research is being developed in the Energiewende Research Forum with the involvement of all of the relevant players – the federal and state governments, business, science and society. The research agenda is being incorporated into the further development of the Energy Research Programme.

The coordination with the German states is of great importance. They provide substantial financial support for energy research. Their programs are tailored to the conditions in their respective state. The states’ total subsidies equalled 253 million euros in 2012. Approximately one-third of the total of publicly funded energy research in Germany was funded by the states. They make an important contribution to the development of energy technologies in Germany (Chapter 4). In order to coordinate with the states, the BMWi organises an annual meeting on energy research between the federal and state governments called the *Bund-Länder-Gespräch Energieforschung*. At this meeting, recent developments and topics are presented and discussed.

1.5 Central Information System for Energy Research

To improve transparency in government funding policy, the central *Information System “Energy Research and Energy Technology” EnArgus* was established within the Sixth Energy Research Programme. The information system EnArgus provides extensive search for details of ongoing and completed projects. Part of the system is available to the ministries and project management organisations. This complements the functions of the government’s project database and thus contributes to an improvement in coordination.

The first public test phase of the EnArgus website is planned to take place sometime in 2014. Here, the information system offers extensive search possibilities for the spending of governmental energy research funding to the interested public while ensuring data security and privacy. The funded projects are displayed retroactively for energy research projects going back to the beginning of electronic file management so that research projects can be indexed back to 1976.

The indexing of the energy research database, which includes over 12,000 funded projects, takes place by means of semantic search capabilities in EnArgus. Due to the automatic inclusion of technical correlations, a search without extensive detailed knowledge is possible. During the test phase, not all areas of energy technology will be searchable. Additionally, the system supports transparency by pre-defined analyses, which can be viewed in detail, and thus allows for traceability down to the project level for future editions of the Federal Report on Energy Research. This ensures transparent public verification for all of the funds in the German government's Energy Research Programme.

The map of energy research has been available on the BMBF's website since March 2013. The map of energy research provides transparency for the first time about the achievements of energy research and the expertise of research organisations, universities and academies in Germany.

2. Project Funding

2.1 Energy Conversion

2.1.1 Photovoltaics

Photovoltaics (PV) is the direct conversion of sunlight into electricity. To achieve this, solar cells made from semiconductor materials are used in modules that are connected together in power units of several hundred watts. These provide direct current which can be subsequently converted into commonly used alternating current.

Photovoltaics can make a significant contribution in the transformation of the electricity supply system towards the use of renewable energy sources. Today, it produces around 5 percent of electricity consumed in Germany. Solar roofs with decentralised electricity fed into the grid are popular with many homeowners. There are now 1.5 million photovoltaic systems on the grid in Germany.

2013 was again a difficult business year for the photovoltaic industry, system installation and suppliers. Worldwide, the current production capacity of 60 to 70 gigawatts is faced with a market of around 40 gigawatts a year. This leads to an oversupply with low module prices, currently in the order of about 0.60 euro per watt. As a result, only the most economical manufacturing sites can be used without making losses. An improvement to the situation is expected at the end of 2014 at the earliest, or perhaps even only in 2015, when manufacturing capacity and markets have reached a level of approximate conformity.

Given this environment, the cost of high-quality solar modules must continue to fall. Current development goals are below 0.50 euro per watt. In regards to the usual system components like inverters, mounting systems and installation, it is clear that a further reduction in electricity production costs is only possible with highly efficient modules and systems.

In 2013, the actual outlays for project funding in the field of photovoltaics was 63.59 million euros (cf. Fig. 3). This included a total of 342 ongoing projects. In 2013, the federal budget committed 49 million euros for new projects. Alongside this, additional government funds for photovoltaics were spent on other technical programs, such as photonics.

In recent years, significant cost reductions have been achieved on both the system and component level. To further promote this development and to realise the expansion potential of photovoltaics economically and efficiently, the target is still set on improving efficiency and realising existing cost-cutting potentials. In the current situation, the priority for funding is to support the German photovoltaics industry, the mechanical engineering industry as well as the suppliers in developing innovative and competitive solutions. Therefore, the government favours collaborative projects with industry participation. At the same time, initial research is possible. This should enable excellent German research institutions to offer ideas, which have already successfully completed the “proof-of-concept” phase, to the industry in four to five years.

The success of this strategy can be seen especially in the positive interim results of ongoing projects in the Photovoltaic Innovation Alliance, like the alliance’s first status colloquium showed at the end of April 2013. The joint funding call by the BMU and BMBF on “Research and Development for Photovoltaics” flanks the alliance. It started in May 2013. By 2014, twelve industry-run projects with a total of up to 50 million euros will be approved from the submitted project proposals.

The same goals were shared by the projects of the “Solarvalley Mitteldeutschland Excellence Cluster.” They were formed as part of the cluster competition and are supported with nearly 40 million euros in budget obligations from the BMBF. They were completed by the end of 2013 and brought forth innovations particularly in the field of silicon wafer technologies.

Silicon wafer technologies are still the standard with around 90 percent of global installations. In the meantime, they have gained a high level of maturity. The manufacturing technologies have also gradually improved in recent years. The PERC technology (passivated emitter and rear contact) is in the market launch phase with cell efficiencies of 18 percent and more. An example of this is the project “High Efficiency Screen Printed Solar Cells with Dielectric Rear Side Passivation and Selective Emitter (HighScreen).” It allows for industry and research to develop concepts for high efficiency PERC solar cells that can be produced on an industrial scale. This also sketches out the way to develop even more efficient, higher quality modules.

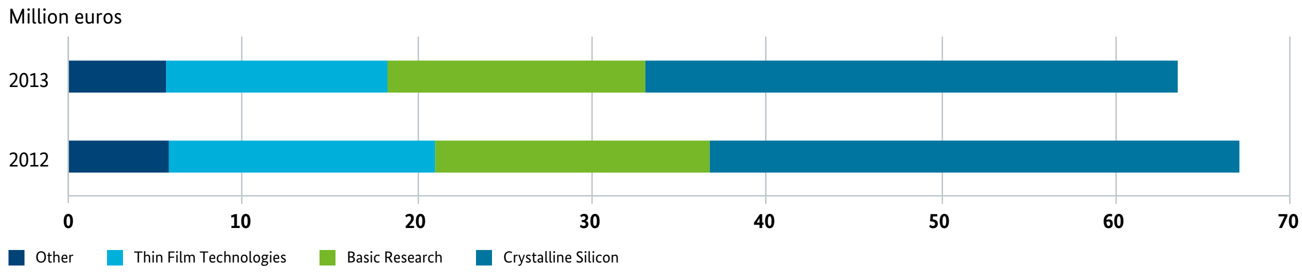
Solar cells based on the CIS thin-film technology (CIS stands for a compound made of the elements, copper, indium and selenium) have proved their high performance capabilities, with an efficiency of 20.8 percent, a world record set in Germany. The continuous improvement of efficiency is made possible by targeted process and material modifications. In the project "Reliability of CIS – Thin Film Solar Cells – RECIS," relevant rapid tests are developed and implemented. The methodology and procedures come from semiconductor technology and are applied to the specific requirements of the CIS thin film technology. These rapid tests include exposure to temperature, light and electrical loads as well as a combination of these. They are meant on the one hand to determine the behaviour of the CIS solar cell in later applications and on the other hand to sort out the relationships between material properties and manufacturing conditions. The primary goal of the project is to ensure a lifespan for solar cells of more than 30 years in the field. This is making an important contribution to reduce the cost of electricity production using photovoltaics.

By funding activities in organic photovoltaics, the BMBF aims to bridge the gap between science and business in this young branch of organic electronics. The main objectives are an increase in the lifespan of cheap, flexible cell encapsulation to prevent degradation by oxygen and water, an increase in efficiency from new cell concepts and absorber materials, as well as the establishment of reproducible roll-to-roll printing processes for manufacturing modules.

The BMBF call for proposals, "Organic Electronics, in particular Organic Light Emitting Diodes and Organic Photovoltaics," started an application-oriented approach in 2011, which should take advantage of the synergies between industry and science to guarantee a subsequent application of the technologies. Within the framework of this funding, a new world record was also achieved in the spring of 2013 with a laboratory cell efficiency of 12.0 percent.

In the near future, the emphasis of research funding will remain on reducing costs at the system level. This means that the focus will remain on both the technology of crystalline silicon in regard to the development of highly efficient modules and quality assurance and reliability of photovoltaic systems. Other topics included in this funding philosophy are solar cells based on the CIS thin film technology and concentrating photovoltaics. Furthermore, the focus is on system technology with a concentration on the interaction of the photovoltaics with the power grid to stabilise the grid or the integration of battery storage to increase private energy consumption, including solar electric cooling systems as well as additional cost reductions for inverters.

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



2.1.2 Wind Power

Energy research in the field of wind power ranges from the technical side of improving the individual critical components of wind turbines to the development of entirely new components and the design of large component test stands for nacelles, rotor blades and load-bearing structures. Strategic objectives still entail contributing to the best performing institutional landscape possible as competent partner for industry, to contribute to cost reductions, to answer open questions about the expansion of offshore wind power in deep waters far from the coast in a cost-efficient and environmentally fashion, and, last but not least, to increase the good competitive position of the German wind industry in a rapidly growing field of competitors. Because onshore wind power energy in Germany is expected to be a significant contribution to the cost-efficient power supply even in the future, the development of hitherto under-exploited sites (forests, mountains) as well as the development of weak-wind turbines plays an important role.

A total of 56 wind power projects with a funding volume of 37.3 million euros was committed in 2013 (see Fig. 4). Compared to the previous year, this represents a significant decrease in the volume of new grant appropriations (2012: 93.2 million euros). Ongoing research projects were supported with 52.6 million euros in pay outs (2012: 38.5 million euros). For both statements, it must be taken into consideration that the years 2011 and 2012 should be viewed separately, because of an increase in the federal budget and a significant increase in resources in the Energy and Climate Fund (EKF). Thus, the volume of new grants from 2006 to 2010 – excluding the EKF exceptions in 2011 and 2012 – amounted to 34.43 million euros on average. The volume of new grants in 2013 even surpassed the already high level of the previous years.

Offshore wind power, in relation to the amount of electricity it provides, does not play a market-relevant role at the moment. Therefore, there has been an emphasis on promoting research in this area in the past few years. Offshore wind power is very important to the German government since the goals set for the expansion of renewable energy are probably unattainable without offshore wind power. A continuous energy supply is more likely at sea due to much more constant wind conditions. There are also suitable open areas at disposal at sea.

One of the goals in promoting research is to contribute to cost reduction. While projects on low-cost and low-noise installations are only attributed to offshore wind power, virtually all other projects are of benefit to onshore wind power through the transferability of their results. Thus, the improvements in reliability and the experiences with multi-megawatt machines can provide an important impetus for the expansion of onshore wind power. This is seen in the recent significantly accelerated development of weak wind sites with long rotor blade spans, high hub heights and, over the last few years, even greater power ratings in the range of three megawatts per turbine.

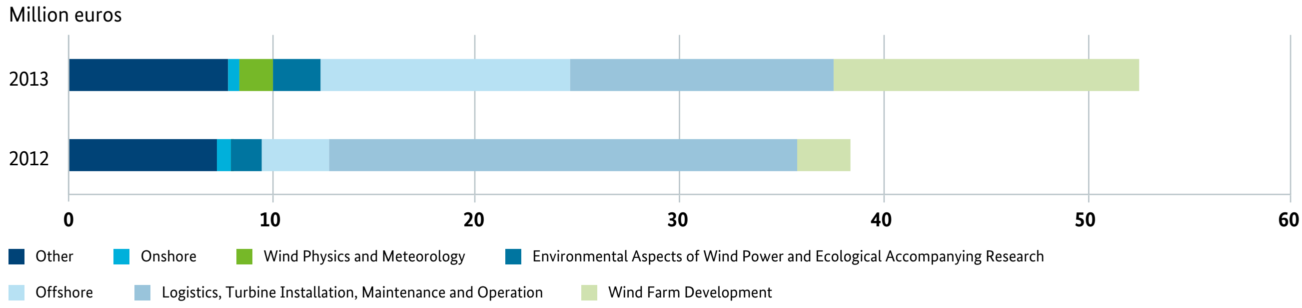
For increasing blade lengths, there needs to be appropriate test stands for production concepts in order to drastically reduce the costs for blade manufacturing and to improve production quality at the same time.

To accelerate the development of existing turbine concepts and the implementation of new development approaches, nacelle test stands are currently being built: in Aachen with funds from the German state of North Rhine-Westphalia and the European Union as well as in Bremerhaven with federal funds. It is expected that one of the important discoveries about the hitherto misunderstood damage mechanisms will be obtained by using this powerful infrastructure.

Several research projects presented their results, for example, at the “EWEA Offshore 2013” conference in Frankfurt. The “FINO Conference 2013” in Kiel provided a good overview of the extensive measurements as well as the results of projects on research platforms in the North Sea and Baltic Sea (FINO 1 to 3).

For the near future, it is expected that the ongoing research into improved designs and automated manufacturing will deliver contributions towards an optimisation of quality and cost in production. Since the construction and operation of offshore wind farms in the German Exclusive Economic Zone (EEZ) has recently received considerable momentum, it must be assumed that there will be a rapid learning curve in regards to logistics during construction and maintenance. In conjunction with the optimisation of individual components, the trend towards longer rotor blades and standardised recording of damages, the reliability of the supply from wind power is increasing, costs are falling and approaches will be supplied for new research questions.

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



2.1.3 Bioenergy

To focus on its important role in the future supply of renewable energy, grid stabilisation and the provision of fuels for mobility and raw materials for the chemical industry, research funding in the field of bio-based energy production has been intensified since 2008 under the BMBF initiative “BioEnergy 2021 – Research for Utilising Biomass.” It has a total volume of 52 million euros. The amount was allocated in almost equal parts to projects involved with thermochemical and biochemical biomass conversion as well as those focusing on the optimisation of power plants. A large part of the projects expired in the fiscal year of 2013.

Due to the unabated high development potential of bioenergy, basic research has been systematically pursued in this area since 2012 with the BMBF initiative “BioProFi – BioEnergy – Process-oriented Research and Innovation” with a total volume of 35 million euros. The initiative places its thematic priorities on the optimised use of residual materials and the process-engineering development of biogas plants in order to improve the load-dependent feed into the electricity grid to compensate for fluctuating power generation from the sun and wind. Furthermore, due to the limited availability of biomass, procedures are being developed for the industrial production of biomass by using algae. Due to the high relevance of this field of research, this point has been expanded into two projects as part of the Sixth Energy Research Programme with a volume of ca. 2.4 million euros even after completion of the BioProFi awarding phase.

In 2013, the BMBF invested a total of around 10 million euros for the funding of basic research in the field of bioenergy and thus maintained the comparably high level of the previous year.

The contribution of BMEL to project funding for renewable energy takes place within the framework of the funding programme for “Renewable Resources.” This includes not only research, development and demonstration projects on energy recovery from renewable resources as presented below, but also other measures not included in the Energy Research Programme, such as the use of biomass as material, public relations work, and consumer advice.

Since 2000, the “Renewable Resources” program has been strengthening its incorporation of energy recovery from renewable raw materials and from residual products and by-products in agricultural and forestry production. The present version of the program was last revised and notified in 2008. The BMEL funding is divided into two fields in bioenergy:

- Production from renewable raw materials with an emphasis on planting and cultivation
- Energy recovery from renewable raw materials.

In 2013, funding paid out amounted to 26.7 million euros, once more increasing significantly in comparison with previous years (see Fig. 5). Funding is focused on the following priority areas:

- Biofuels from lignocellulose
- Biotechnological production of liquid hydrocarbons for use as a biofuel
- Microbiological processes in biogas plants
- Current cultivation strategies in the area of renewable raw materials
- Cultivation of energy crops
- Solid biomass fuels
- Cultivation of energy crops adapted to climate change
- Intelligent solutions for the combined use of bioenergy and other renewable energies
- Efficiency increases for decentralised bioenergy utilisation concepts
- Development of conversion routes for the supply of energy from renewable resources by means of algae
- Biofuels
- Studies on the humus and nutrient effects of organic raw materials from biomass conversion facilities.

2.1.4 Deep Geothermal Energy

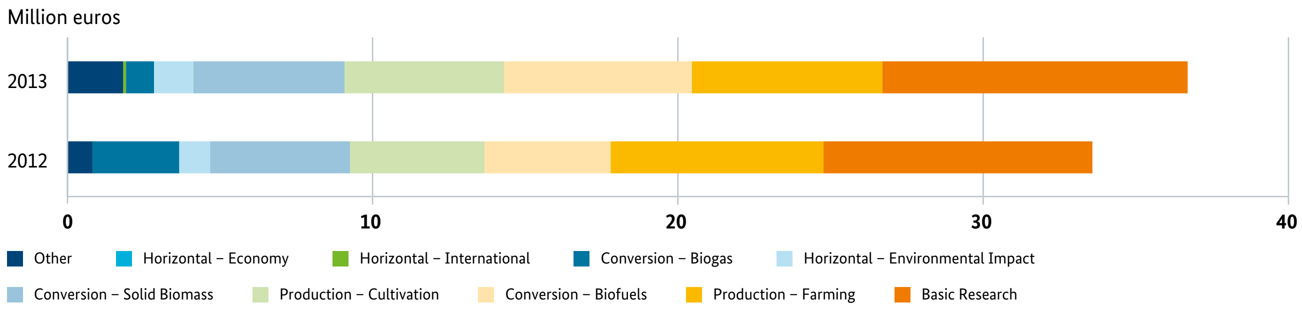
Geothermal energy is a source of energy which, in contrast to fluctuating wind and solar power, is continuously available. In addition to the direct use of heat, geothermal energy is also of interest for electricity production and can therefore play an important role in a renewable energy mix of the future.

Even though there were significant scientific and technological advances in the field of deep geothermal energy utilisation for electricity generation, geothermal energy is still not at a stage where this technology can be used reliably on a commercial scale.

Given the significant potential of geothermal energy in regards to a system supported by renewable energies, the BMU has committed funding for a total of 25 projects with funding amounting to 19.2 million euros in 2013. At the same time, around 17.1 million euros were paid out to ongoing research projects (see Fig. 6).

The projects supported with subsidies included all levels of geothermal energy, from the planning and exploration phase to the drilling, deployment and construction phase up to the testing and operation phase. The subsidised research projects always have the goal of further lowering the cost of geothermal energy, to drive them into the area of the profitability.

Figure 5: Funding for Bioenergy
(See data in Table 2)



While originally technical development was the focus of initial funding, concepts for improvements in public relations have now become a self-evident part of successful research projects.

In Germany, the Molasse Basin in the south, the Upper Rhine Graben in the southwest and the North German Basin are particularly suited for geothermal use. According to the Bundesverband Geothermie e.V. (German Geothermal Association) in 2013, there were 25 geothermal power stations in operation in Germany with an installed capacity of 222.95 thermal MW, which supplies households, businesses and public buildings with heat energy via district heating networks.

Up to now, the four plants in Insheim and Landau (both Rheinland-Pfalz, 2007), Unterhaching (Bavaria, 2008/09) and Bruchsal (Baden-Württemberg, 2009) have been developed to generate electricity and together have an installed electric output of 12.31 MW. In addition to these, there were five more plants under construction in 2013: Dürrnhaar, Kirchstockach, Irchweidach, Sauerlach and Traunreut (all in Bavaria).

While the projects mentioned mostly employ hydrothermal geothermal energy, using existing thermal waters, the exploration of hot dry rock in petrothermal geothermics will occupy a permanent position in further project funding.

2.1.5 Power Plant Technologies

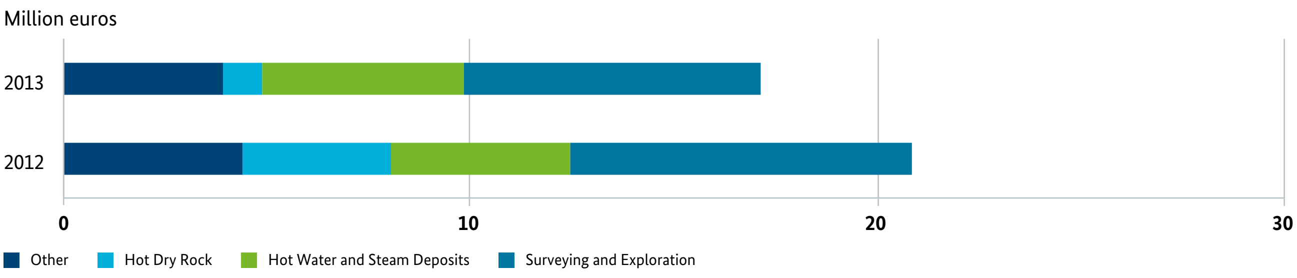
While in the past, issues such as efficiency, availability and profitability were placed in the foreground in regards to energy conservation and efficiency in the field of power plant technology and carbon capture technologies, questions relating to the flexibility of processes and components are gaining in importance in the wake of the Energiewende. The reason for this is the increasing demand for power supplied by fossil-fuel fired power plants to be able to compensate for the residual load between generation from renewable energy sources and consumption in a timely fashion[2].

In 2013, the subsidies paid out to projects for power plant technology and CCS technologies amounted to 23.75 million euros (see Fig. 7) in 214 ongoing projects. 64 new grants were issued with a total commitment of 24.7 million euros.

In 2013, a number of large collaborative research projects were successfully completed. Examples of these projects were ADECOS and MEM-OXYCOAL. ADECOS dealt with the development of oxy-fuel technology based on cryogenic air separation and MEM OXYCOAL focused on the development of CO_2-resistant membranes for the production of O_2 for oxy-fuel processes.

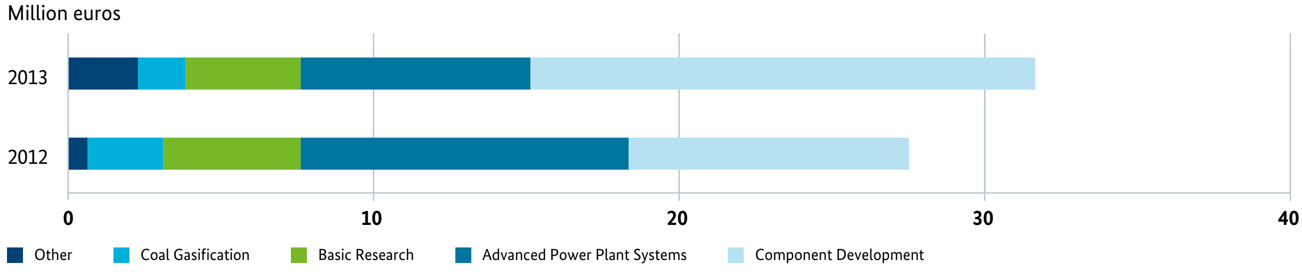
The collaborative project COORAL, which was devoted to the transport of CO_2, was also completed and is to be continued under the name CLUSTER with significantly expanded topics.

Figure 6: Funding for Deep Geothermal Energy
(See data in Table 2)



2 See http://www.kraftwerkforschung.info

Figure 7: Funding for Power Plant Technologies
(See data in Table 2)



With the launch of the program COOREFLEX Turbo in 2013, the turbomachinery working party, AG Turbo, has started a new phase which will continue until the year 2017. Here too, the focus on flexibility (fuel and operation) was strengthened.

The start of the projects in the context of the Clean Energy Center (CEC) also drove forth a whole project package that mainly deals with flexible, yet low-emission combustion technologies particularly designed to enable significantly expanded partial load ranges.

The so-called Rhine-Ruhr Power Cluster combines the work that is necessary in connection with highly efficient and flexible conventional power plants. It began with the joint project "Partner-Dampfkraftwerk." The idea behind Partner-Dampfkraftwerk (steam power plant) was to form a long term partnership for a secure power supply between renewable energy and conventional power plant technology.

At the international level, Germany continued its participation in the field of power plant technologies and CCS in 2013. This was done through the involvement and participation in the IEA Working Party on Fossil Fuels, the IEA Implementing Agreement Clean Coal Centre (CCC), the committees and task forces of the European Commission's Zero Emissions Platform (ZEP), as well as activities within the framework of the SET-Plan and bilateral cooperations.

The BMBF supports research on the storage of carbon dioxide in underground geological formations within the framework of the GEOTECHNOLOGIES Special Program. This should resolve basic questions about the safe storage of the greenhouse gas. The work in the current funding period is concentrated on the topics of long-term security and the development of monitoring methods for the operational and post-operational phases of a CO_2 storage facility. The CO2MAN project was completed in 2013. One of the tests carried out in this project was the storage of carbon dioxide in a deep aquifer in Ketzin (Brandenburg). The follow-up project COMPLETE will sponsor the sealing of the storage facility and the post-operational phase with funds from the BMBF starting in 2014. The BMBF provided 3.8 million euros for research for geological CO_2 storage within the framework of the Energy Research Programme and an additional 3.5 million euros from other programs.

2.1.6 Fuel Cells and Hydrogen

Fuel cells offer an efficient technology that generates electricity with high degrees of efficiency in small units. In motor vehicles, fuel cells contribute to electric mobility with a range that is comparable to conventional vehicles. In the domestic energy supply, they allow for the combined generation of electricity and heat. In UPS systems (UPS: *Uninterruptible Power Supply)* or off-grid systems for electricity generation, fuel cells allow for efficient and responsive power generation independent from the power grid.

Fuel cells need hydrogen as a source of energy. Hence in situ, they are emission-free in all applications, which is particularly beneficial for applications in mobility or off-grid power generation. The production of hydrogen using electrolysis is also an important option to make use of surplus electricity and thus constitutes a link between fuel cell efficiency technology and the demand for energy storage technologies.

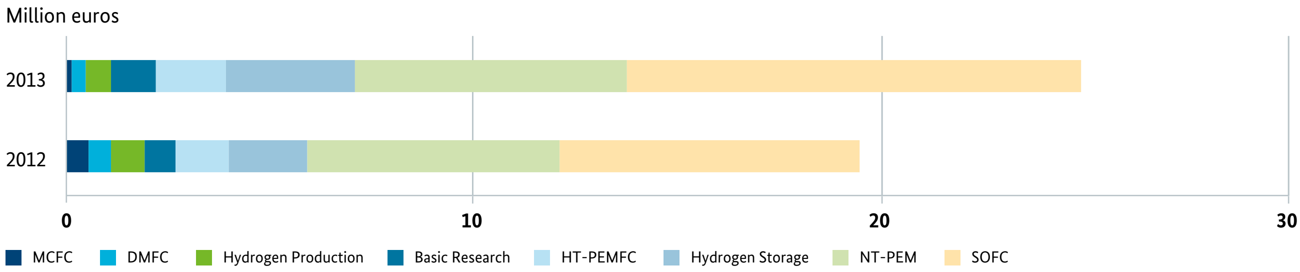
The government departments involved in the Energy Research Programme support application-oriented projects for the development of fuel cell technologies with energy research funding. In doing so, they make up a substantial part of the *National Hydrogen and Fuel Cell Technology Innovation Programme (NIP).*

In 2013, a total of 112 projects received payouts of 23.8 million euros (see Fig. 8). In the foreground are technologies on PEM fuel cells and SOFC as well as hydrogen tanks for mobile applications. Projects that were supported to a lesser extent included DMFC development and the development of high-temperature electrolysis (SOEC)[3]. There were 26 new projects approved in these technology fields.

The following projects are of strategic importance:

- In the joint project HYMOTION 5, five partners are developing a concept for an automotive-grade PEM fuel cell stack, which can be manufactured completely in Germany.
- In the joint project OPTIGAA2, parts suppliers for the automotive industry are also being funded to produce improved components for PEM fuel cell stacks for cars. In both projects, the concepts are focused on improved and long-lasting components that can be cost effectively produced at the same time.
- SOFC technology, which is of interest for combined heat and power generation in the home energy supply, is being developed in three projects. A breakthrough is expected here in the performance characteristics of lifespan, cycle stability and cost.
- In addition to this, a project between two German and two Finnish partners is fundamentally investigating the degradation mechanisms of SOFC.
- In addition to inexpensive fuel cell stacks, the market launch of fuel cell powered vehicles also requires hydrogen tanks with a significant reduction in costs. The project HYMOD aims at determining the design methods for the construction and securing of hydrogen tanks.

Figure 8: Funding for Fuel Cells and Hydrogen
(See data in Table 2)



3 PEM stands for *proton exchange membranes*, SOFC for *solid oxide fuel cell*, DMFC for *direct methanol fuel cell* and SOEC for *solid oxide electrolyser cell*.

- The “German Canadian Fuel Cell Cooperation,” which was successfully completed in 2012, has continued to be expanded in the “German-Canadian Co-operation on Kinetics and Mass Transport Optimisation in PEM Fuel Cells (GECKO)” since 2013. It aims at optimising components of low-temperature PEM fuel cells for mobile applications. The overall objective is the reduction of transport-related CO_2 emissions. The German consortium and the Canadian partners are the world’s leading institutions in the field of fuel cell technology and are pursing complementary approaches in the project. In the year 2013, the project received 1 million euros in funding from the German side and maintained the high levels of previous years.

Based on the published figures for the planned market launch by well-known manufacturers of boilers, UPS systems, and automobiles, the prospects for fuel cell technologies are good. The projects presented in this section are already aimed in part on the subsequent generations of the associated technologies, of which a further reduction in costs and an increase in lifespan is expected. The aim of the projects presented here is to investigate the improved technologies in field tests and to prepare for their subsequent commercialisation.

2.1.7 Solar Thermal Power Plants

Solar thermal power plants use the sun to generate electricity. Mirrors focus sunlight onto a solar receiver (CSP – *concentrating solar power)* and heat up a heat transfer medium located there. A conventional power plant process converts this energy into electricity. Solar thermal power plants are suitable for generating electricity in regions of the world with high levels of direct solar radiation. Their great advantage is that they provide needs-based solar power through integrated power storage systems. Thus, they significantly increase the ability to integrate fluctuating renewable energies even in smaller grids. The possibility of partially combining solar thermal power into fossil-fired power plants to build so-called hybrid power plants allows for the gradual introduction of solar power into the energy supply.

Despite significant technological advances in recent years, the expansion of CSP for electricity generation has been subdued in comparison with other renewables for the past two years. This has led to a significant reduction in production capacity and business closures even among German component manufacturers and suppliers. The competition from foreign companies, which often have significant geographic advantages for pilot plants, is growing. Also, the relatively low revenues prevent cost reductions due to the economies of scale.

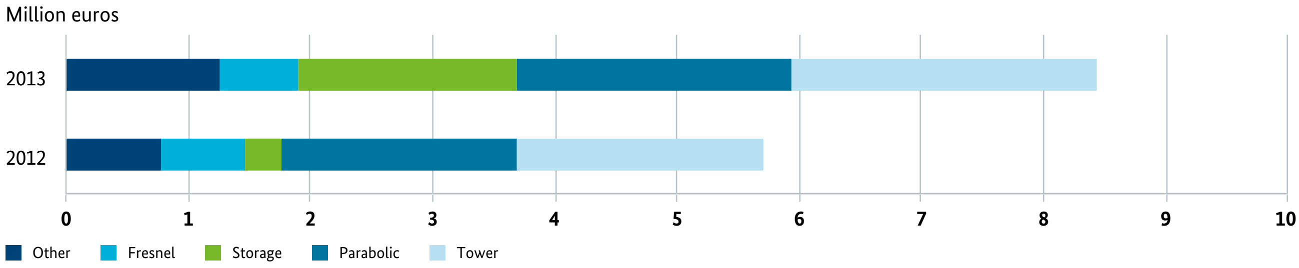
Nevertheless, German companies occupy important positions in the international CSP market. For example, this is seen in the power plant project “Schams 1” in Abu Dhabi (United Arab Emirates). It is a 100 MW parabolic trough power plant that went into service in March 2013: the mirrors, receivers and turbine were “Made in Germany.”

In 2013, the use of subsidies for project funding in the area of solar thermal power plants amounted to actual outlays of 8.4 million euros (see Fig. 9). This included a total of 74 ongoing projects. For new projects, 8.7 million euros were appropriated in the federal budget.

Components for solar thermal power plants produced in Germany still maintain a prominent position in terms of performance and quality. Against this backdrop, measures for the standardisation and qualification of all power plant components are an important part of research. This helps to underline the high quality of German technology and to support the competitiveness of German companies. For example, the Testing and Qualification Centre for Concentrated Solar Technology QUARZ at the German Aerospace Center (DLR) developed standardised measuring methods for quality control and drew up detailed analyses for the efficiency of collectors.

Molten salt is used successfully today in solar thermal parabolic trough power plants as a storage medium. The benefits of salt can only be fully exploited when it is used not only to store heat but also as a heat transfer medium at the same time. Direct Molten Salt (DMS) power plants do not only ensure predictable power plant performance, but also lower electricity costs through more annual service hours. The project “Demonstration of Molten Salt as Heat Transfer Medium in a Linear Fresnel Collector (DMS Fresnel)” is to yield experimental proof that molten salt is a suitable heat transfer medium in Fresnel collectors. High process temperatures of ca. 550 °C can be achieved through the molten salt.

Figure 9: Funding for Solar Thermal Power Plants
(See data in Table 2)



In addition to the qualification and quality assurance of plant components as well as the further development of DMS technology, another focus of research funding is on the development of solar tower power plants, not only with respect to their use of DMS technology, but also with an eye towards volumetric receivers and pressure technologies. All the mentioned variants allow for operations at temperatures significantly higher than 400 °C. In the field of volumetric receivers technology, German companies have also achieved a lead in development.

2.2 Energy Distribution and Energy Use

2.2.1 Storage

Energy storage plays a major role in the energy system of the future. The storage of electrical energy can help to integrate excess electricity generated from renewable energy sources into the system and to make it available again at times of low power feeds from renewables. In addition to balancing out these fluctuations, local grid overloads can also be avoided with storage technology. To what extent adequately sized storage facilities (e.g. hydrogen in underground caves) allow for an effective seasonal storage of energy is currently being studied.

Furthermore, battery storage makes it possible to electrify the transport sector and reduce dependence on oil and natural gas imports.

Storage of thermal energy could help to reduce primary energy consumption and the associated CO_2 emissions from generating heat for buildings and cities. For example, thermal waste from industrial facilities, which otherwise would go unused, can be transferred locally and at different times, and be used along the lines of energy efficiency as a supply of heat.

Since in many cases storage requires the conversion of electricity into hydrogen, synthetic natural gas or heat, a switch, furthermore, is possible in transport tasks from transmission systems for electric energy to gas pipelines or from the distribution network to district heating networks is also possible. This poses questions of an even closer linkage between electricity, fuel and other energy infrastructure.

The high demand for storage necessitates even more extensive research and development. Researching new technologies, new materials and concepts is required to reduce costs for storage, for example, in the design of communities with large thermal or battery storage facilities. Also, many storage technologies are limited in their potential for expansion so that the energy industry needs different options for large-scale implementation. The most prominent example of these are pumped-storage plants, which can only be realised in regions with suitable elevations. Also underground hydrogen or compressed air storage place demands on the underground that cannot be met in all of Germany. Battery storage places no demands on the geology, but as of yet it is not suitable for seasonal storage.

Energy Storage Research Initiative

To stimulate development of storage technologies, the German government started the Energy Storage Research Initiative in 2011 and greatly increased the existing funding opportunities. Money for the funding initiative comes mostly from the Energy and Climate Fund, which substantially complements the funds from the federal budget.

In the framework of the funding initiative, there are currently 254 funded projects with 191 million euros in budget appropriations. 39.9 million euros were paid out to these projects in 2013. There are also additional payouts amounting to 19.4 million euros for projects in the field of energy storage that are not integrated into the funding initiative (see Fig. 10). In particular, the research initiative includes the two flagship projects "Combined Wind-Hydrogen" ("Wind-Wasserstoff-Kopplung") and "Batteries in Distribution Grids" ("Batterien in Verteilnetzen") as well as the focus area "Storing Heat" ("Wärme speichern").

The flagship project *Wind-Wasserstoff-Kopplung* unites various projects about the development of electrolysers, basic research on geological formations, the uses for generated hydrogen, methanation technologies and the accompanying studies on energy-economic and safety aspects. In the demonstration project WOMBAT for example, converting electricity to hydrogen or methane (power to gas) is being tested on an industrial scale. An existing biogas plant was enlarged into a demonstration plant for this project. The methane is produced with a capacity of 6.3 MW under real operating conditions. It will also be explored to see if balancing energy to stabilise the grid can also be made available with this. To complement this, the highly innovative technology of the PEM electrolysis on 2 MW scale will be designed, built in the project "Energiepark Mainz", and operational tests will start in 2016.

Electrochemical storage offers an alternative to storing hydrogen from electrolysis. The projects are mostly combined in the flagship project *Batterien in Verteilnetzen* and range from basic research on anode and cathode materials to the development of new battery concepts or concepts for redox flow storage to the setup and operation of larger units in real life grid operations. Examples of this are the projects "Smart Region Pellworm" and "M5BAT" in Aachen. In Pellworm, a variety of small battery storage units form a hybrid storage system consisting of a lithium-ion battery (power 560 kW, capacity 560 kWh) and a redox flow battery (power 200 kW, capacity 1,600 kWh) as well as a variety of controllable, distributed electricity consumers and producers (e.g. storage heaters, heat pumps). The M5BAT project assembles a battery power of 5 MW with various technological approaches in one place and makes them available as a provision of balancing power starting in 2015.

In addition to an improved storage of electricity, enormous potential is hidden in the field of heat utilisation and storage. As part of the research work in the focus area "Storing Heat," the storing of latent heat in the phase change and reaction heat from chemical reactions are being explored. Both issues are being addressed in the field of basic research as well as application-oriented aspects.

The website for the funding initiative[4] includes a graphic representation of projects supported by the funding initiative and contributes to the documentation of the progress in the development of storage technology.

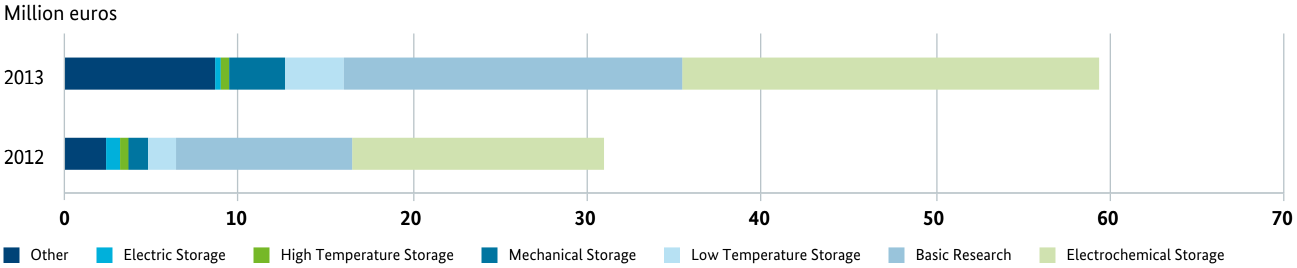
Battery Research

The development of batteries for electric vehicles is being supported by the funding concept "Key Elements of Electric Mobility in the Energy Sector" with money from the Energy and Climate Fund. In 2013, 36 projects in this funding priority benefited from 12 million euros in subsidies. A new approval was the project "Drive Battery". Its aim is the development of cost-effective and long-lasting power electronics for electric vehicles.

Since 2008, the Federal Ministry of Education and Research (BMBF) has been funding the application-oriented basic research for electricity storage with the "Innovation Alliance Lithium-Ion Battery LIB2015" within the framework of the German government's high-tech strategy. The BMBF supports this consortium with over 50 million euros in funding, of which 2.65 million euros were paid out in 2013.

4 See http://forschung-energiespeicher.info

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



The BMWi also contributes funding within the framework of two joint projects. Overall, the German government committed funds of 60 million euros to the Innovation Alliance for the whole duration of the projects.

International Activities

In the framework of the International Energy Agency's (IEA) international research project "Integration of Renewable Energies by distributed Energy Storage Systems" in the implementing agreement "Energy Conservation through Energy Storage" ECES (Annex 28), scientists from all over the world are cooperating under German leadership to answer basic questions about energy storage in the future energy system. At the moment, central energy storage technologies, such as pumped storage plants or power-to-gas, are at the centre of the discussions. The potential of Decentralised Energy Storage (DES) is still largely unexplored. This is defined by its location within an energy system, which is usually on the consumer side. In the case of an electrical grid, this would be in the low voltage distribution network or in a district heating network in the area of heat transfer stations or beyond. With a growing decentralisation in renewable energy production, only DES can compensate for these local variations.

2.2.2 Power Grids

Further expansion of renewable energy sources means an increase in the portion of fluctuating power generation. These changed conditions place new demands on the combined effects of conventional and renewable power production as well as grid expansion and construction. Energy research in the field of power grids is therefore pursuing targets to accelerate the expansion of the electricity grid infrastructure and orienting it towards the feeding in of high levels of renewable energy through new methods, concepts, technologies and materials. Project funding includes the conversion of distribution networks into smart and automated grids with new equipment and enhanced technologies for system security, monitoring and communication. Moreover, new transmission technologies are being studied, such as high-voltage direct current (HVDC) and its integration into the existing three-phase grid. In addition, there is also a focus on aspects of planning, acceptance and the structural design of power lines.

The German government paid out 31 million euros for project funding in the field of power grids in 2013 (cf. Fig. 11). In 2013, new projects with a funding volume of 42 million euros were approved. The figures from the interdepartmental research initiative "Zukunftsfähige Stromnetze" ("Future-proof Power Grids," see below) are effective starting in 2014.

In recent years, many advances have been made. These can be differentiated thematically. According to a report by the Joint Research Centre of the European Commission from 2013 about projects with the focus of smart grids ("Smart Grid Projects in Europe: Lessons learned and current developments: 2012 update"), Germany is one of the leading players in smart grid projects in Europe. A successful example of research funding in this field is the initiative "E-Energy." A total of 8,500 consumers in six test regions took part in the program, which was completed in 2013. It was a joint project between the Federal Ministry for the Environment and the Federal Ministry of Economics. It focused on decentralised solutions for balancing the differences between electricity generation and consumption. As a result of field trials, there is now valid information on the potential of load shifts and decentralised network operation with high proportions of renewable energies. Additionally, aspects of interfaces and standards have been worked out.

On the structural design and planning of overhead power lines, the joint projects “Kompakthöchstspannungsmasten und -Traversen (KoHöMaT)” (compact highest-voltage masts and trusses) and “Raumoptimierte Freileitungen” (space-optimised overhead power lines) are pursuing the goal of reducing the required area for overhead power lines through new forms for masts. KoHöMaT is studying high-voltage masts made from ultra-high performance concrete with a compact geometric arrangement of the conductors. The project “Raumoptimierte Freileitungen” is exploring new chain constructions and rope systems that reduce the slack in the conductors and it is testing new mast forms for this as well. Furthermore, the project “Bewertung und Planung von Stromnetzen” (power grid evaluation and planning) is researching an objective evaluation tool for power lines based on mathematical methods. By using these optimisation techniques, which take into account the varied and complex criteria in the planning of routes for grid expansion, possible routes can be evaluated objectively. The common goal of both projects is an improvement in acceptance for overhead power lines.

In the area of “smart grids,” an active smart power grid station was developed in the framework of a collaborative project to increase the uptake capabilities of low-voltage power grids for renewable energy. As a result of this, load flow reversal as well as power grid recovery and overvoltages can be avoided especially in rural regions with large portions of photovoltaics, lower loads and long power grid branches. Due to the proven characteristics, a strong demand has arisen for this technology on the part of the distribution network operators.

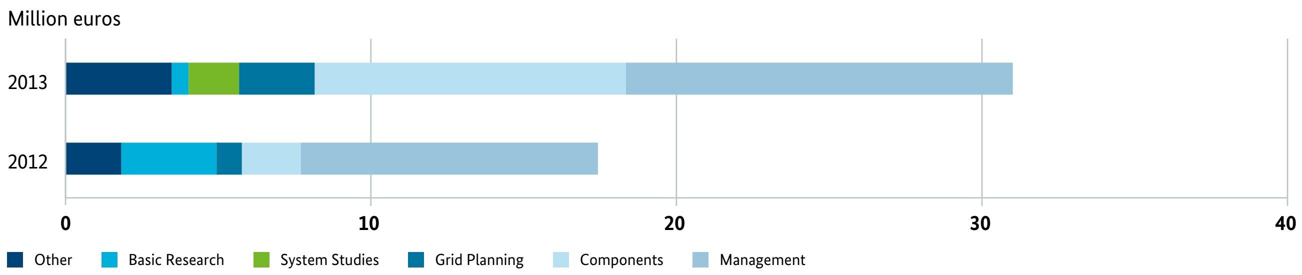
On the question of system security, a real world field test showed how renewable energy can yield primary control-energy capacities as an alternative to conventional power plants and thus can ensure frequency stability. For this purpose, renewable generation facilities were merged into a combined cycle power plant. The forerunner project demonstrated that renewable energy can always cover the electricity demand.

As part of a competition, “Future Electrical Networks” (FEN) was selected as one of ten campus models from over 90 applications in September 2012. Each is endowed with approx. 1-2 million euros/year from the BMBF complementary to their own contributions for a funding period of up to 15 years.

The topic of the “Future Electrical Networks” research campus is the exploration of DC voltage grids for electricity transmission and distribution.

The investment project “Multi-Megawatt Laboratory” at the Fraunhofer Institute for Solar Energy Systems (ISE) has the goal of creating a laboratory facility for research projects to develop new power electronic components (e.g. converters) with a power consumption of up to 10 MW. For this purpose, three research laboratories are being installed at the Fraunhofer ISE: a high-voltage, a medium-voltage and a low voltage laboratory. In the future, additional installations for broadband conversion, control and measuring high currents, voltages and powers, as well as for the simulation of renewable energy power plants, will allow for the processing of a number of important research questions about the interplay between networks and future photovoltaic power plants, technologies for new generations of central inverters and the further development of standards and feed-in policies.

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



The "Zukunftsfähige Stromnetze" Research Initiative

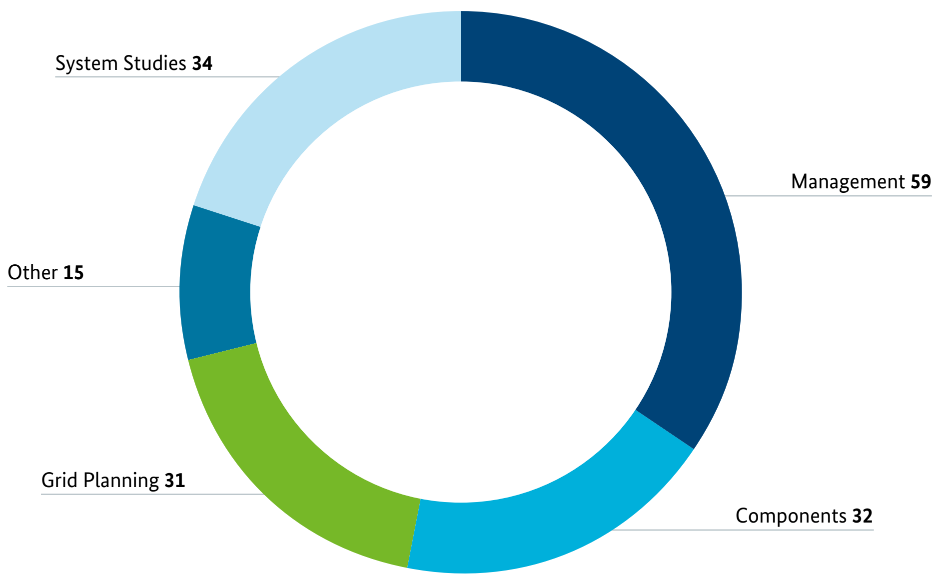
Research for the conversion of the power grid infrastructure for high feed-in volumes of renewable energy in the transmission and distribution grids is at the heart of the interdepartmental research initiative "Zukunftsfähige Stromnetze" ("Future-proof Power Grids"), which the German government started in 2013. It is part of the Sixth Energy Research Programme and has a volume of up to 150 million euros. The initiative thus strengthens ongoing funding activities in this field[5].

The funding initiative aims to facilitate improved cooperation between business and science along the whole length of the value chain as well as with international research collaborations. Altogether, environmental sustainability, profitability and resource efficiency of power grids and the security of the electricity supply in Germany are to be optimised. Due to its structure, the existing power grid is suitable only to a limited extent for the future requirements and constraints of a power supply based largely on regenerative energy sources. The necessary technological requirements and innovations need to be created for a long-term secure, affordable and environmentally friendly power supply in this area, which is so important for the implementation of the Energiewende. Numerous studies and development plans confirm similar requirements and needs (e.g. dena – grid study or grid development plan).

The funding initiative met with a keen interest in industry and research institutions. A total of 171 project proposals were submitted (see Fig. 12). Thus, around 400 companies participated in the planned research joint projects, including 160 small and medium-sized enterprises (SMEs). Moreover, nearly 300 higher education institutions and research institutes are involved in the projects.

A number of project proposals for the funding initiative deal with topics of smart distribution networks, transmission systems as well as network control procedures and ancillary services. Here, already 55 proposals with a funding volume of around 105 million euros have been invited to submit their applications. The first projects are expected to be approved in the course of 2014.

Figure 12: Project Proposals Submitted for the Funding Initiative "Zukunftsfähige Stromnetze"



5 http://www.forschung-stromnetze.info

2.2.3 Energy Efficiency in Buildings and Cities

Today, urban areas account for three-quarters of the world's greenhouse gas emissions. Therefore, cities and municipalities are the focal point for many of the necessary energy efficiency improvements and create the conditions for the implementation of these improvements, e.g. in the form of construction plans and standards for energy supply structures. In addition, they are shareholders in the local and regional companies and thus can affect the energy efficiency of urban infrastructure. It is crucial that innovative concepts are supported by all societal players. The living environment of the city needs to be not only climate-friendly but also attractive and forward thinking.

EnEff:Stadt and EnEff:Wärme

With the funding priorities of EnEff:Stadt (energy efficient cities) and EnEff:Wärme (energy efficient heat), the BMWi is intensifying long-term research activities for more energy efficiency in municipal areas. With ambitious demonstration projects in typical urban districts, practical experience is being collected in the application of new technologies and planning tools, as well as in implementation management and the optimisation of operations. The trend is moving towards increasingly complex projects involving heating, power grids and data networks. A knowledge platform with pooled expertise and information services for intercommunication is being created through practical workshops and project manager meetings[6].

In 2013, 98 projects were provided with a total funding payout of 76.2 million euros (cf. Fig. 13). 18 new projects were approved with a total committed federal budget of 14.7 million euros. Highlights of the year were:

- Field tests for absorption refrigeration technology for CCHP systems
- The cluster project "HighTech-LowEx" Energy Strategy Berlin Adlershof 2020
- The international cooperation D-A-CH "Energy Efficient Cities" in Karlsruhe, Salzburg and Winterthur

Energy Efficient Cities Competition

The BMBF's "Energy Efficient Cities" competition has the goal of increasing energy efficiency in cities and municipalities. The tender is aligned with the German government's climate change objectives and the respective municipal structures and functions. The objectives of the competition are:

- Developing and implementing pioneering ideas
- Considering the "city system" as a whole
- Innovations in services play a key role

The competition aims to provide practical knowledge for municipal practice and to foster innovation in business and society.

The winners were Delitzsch, Essen, Magdeburg, Stuttgart and Wolfhagen. These municipalities are being funded until 2016 to practically implement their ideas. The pilot projects should be an example and provide an impetus for other cities. The funding paid out amounted to 4.2 million euros in 2013.

National Platform for the City of the Future

In the National Platform for the City of the Future, experts from local authorities, science and industry are developing an overarching strategic research agenda with the aim of a CO_2 neutral and climate-adapted city. Ongoing programs are to be better coordinated and research projects at different levels are to be networked with each other. Funding paid out for these amounted to 0.27 million euros in 2013.

The topics are:

- Reduction of energy and resource consumption
- Adjusting the infrastructure for climate change
- Civic participation
- Research for a long-term integration of city systems

6 See http://www.eneff-stadt.info

Development of a European Energy Olympics

The Solar Decathlon, an international university competition, is an experimental showcase for the prominent discussion of zero and plus energy homes. The competition will take place in Versailles, France in summer 2014. As a consequence of the "Declaration of Madrid" in 2010, the proposal was made to develop a European format of the event in order to respond to the special conditions of urban density and the necessity of confronting existing buildings. In this context, the evolution of the Solar Decathlon into an Energy Olympics will be discussed. This should include several competition categories in the urban context on various levels from components to climate-neutral accommodation and transport at a major event.

Energy Efficiency in Buildings

The rise of multidisciplinary projects was characteristic of the research in the field of energy efficiency in buildings in 2013. This manifests itself in a closer linking of the fields of EnEff:Stadt und EnEff:Wärme and the research initiatives of energy storage and power grids. This has reduced the proportion of demonstration projects in favour of a stronger focus on research and development. The series of events will be continued on specific topics[7].

On the international level, active participation in the IEA programs Energy in Buildings and Communities (EBC) and Solar Heating & Cooling (SHC) has become more constant.

In 2013, 218 projects for energy efficiency in buildings received funding outlays of almost 138 million euros. Among these are 50 newly approved projects with a committed budget amounting to 26.1 million euros.

The newly approved proposals range from material developments in lenses and coatings on transparent films, to numerous individual projects on commissioning, optimisation and monitoring (*EnBop)* through to the participation in the international university competition Solar Decathlon Europe 2014 in Versailles, France. Teams from Frankfurt am Main and Berlin took part as well as a German-American team with the participation of the Erfurt University for Applied Sciences.

Specially designed for school projects, the BMWi led the workshop "Energieeffiziente Schule" (energy efficient schools) within the framework of the congress "Zukunftsraum Schule" (schools of the future).

Low-temperature Solar Thermal Energy

Today, a high degree of technological maturity has been reached in the classical application fields of low-temperature solar thermal energy. Through research and development as well as learning-curve effects, the cost of solar thermal was halved from 1995 to 2010. To further enhance the competitiveness of solar thermal energy, innovations are necessary particularly at the system level. These include, among others things, more standardisation, easier installation through prefabricated systems and optimised functional reliability and yield security.

In 2013, payouts for project funding in the area of low-temperature solar thermal power amounted to 8.4 million euros for a total of 95 ongoing projects. In 2013, federal budget appropriations for 9.9 million euros for new projects were approved.

Research approaches on integrating systems have been heavily promoted in recent years. An example is the project "EAHplus Monitoring: Developing a new generation of energy self-sufficient houses – metrological monitoring." It intends to garner information about thermal and electrical energy flows.

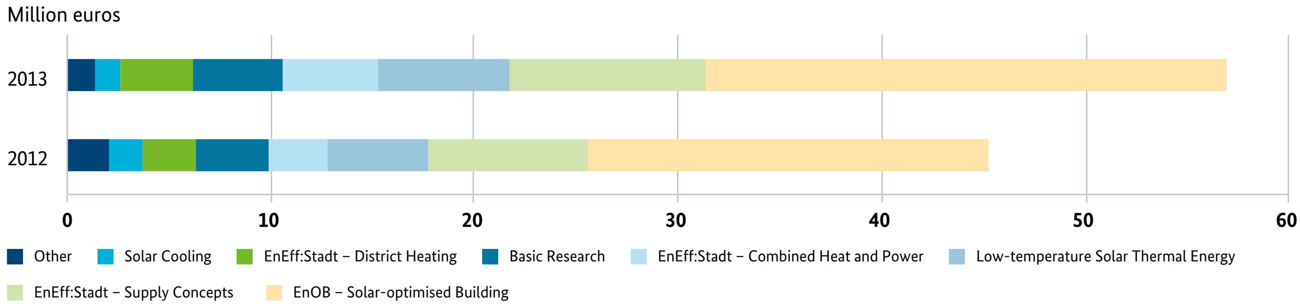
The joint project "Solar Thermal in the City's Energy Supply (EnWiSol)" deals with solar thermal power in the urban energy supply. The aim of the project is an energy-economic review of solar thermal systems in urban energy supply and the development of management strategies for heat supply systems on the basis of combined heat power (CHP) in conjunction with decentralised solar thermal generation.

The funding activities are continuously reflected in the state of the technology. Additionally, regular workshops and conferences have been started, such as the Third Solar Thermal Technology Conference in January 2013.

The focus of research funding is currently on reducing the costs of the systems. There are also concepts in view

7 See http://www.enob.info

Figure 13: Funding for Energy Efficiency in Buildings and Cities
(See data in Table 3)



for solar energy-plus houses or solar active houses or houses with a 100 percent renewable energy supply in newly constructed buildings and in the modernisation of existing buildings. Even the development towards solar neighbourhood solutions is a central theme of funding. Other research activities relate to the future markets of "solar cooling" and "solar process heat."

2.2.4 Energy efficiency in Industry, Commerce, Trade and Services

Project funding for energy research in the field of energy efficiency in industry as well as commerce, trade and services (EnEff IGHD) ranges from energy optimisation of individual process steps to the development and introduction of new technologies and system components all the way to complex concepts on utilisation of the power supply and waste heat[8]. Here, energy-intensive sectors, processes and industrial products, which can often achieve big energy savings through project funding, continually take centre stage. Alongside these, cross-application technologies that can be employed in a wide range of sectors are developed, such as heating and refrigeration techniques, crushing and separation methods as well as measurement, control and regulation techniques. Because in many areas, the physical limitations of energy conservation are now within sight, the development of novel processing techniques is being particularly promoted.

In 2013, the subsidies for energy efficiency projects in industry, commerce trade and services (EnEff IGHD) payouts amounted to 36.23 million euros for 254 ongoing projects (see Fig. 14). In 2013, 49 new applications were approved with a total committed funding amount of 34.8 million euros.

Major research findings from the development projects completed in 2013 on low friction bearings, more energy-efficient cold and heat pumping, and cleaning technology were presented to the public in relevant national and international events and workshops.

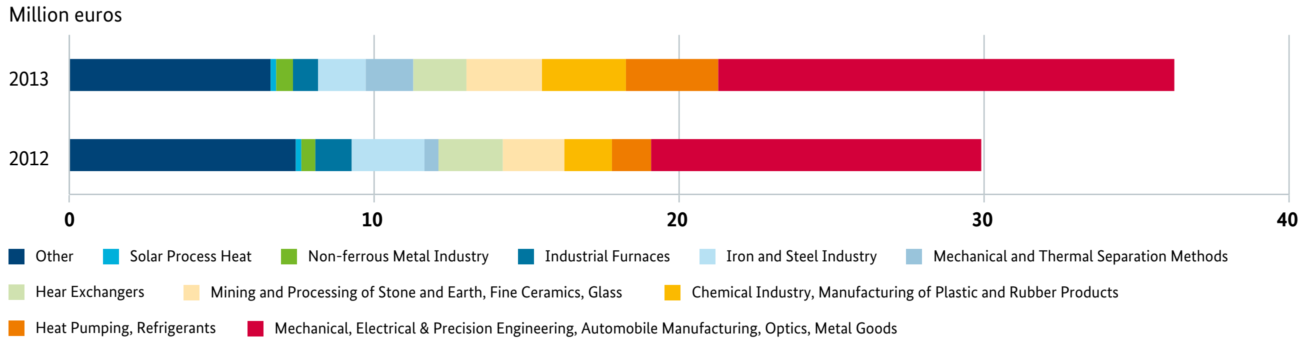
Additionally, innovative and large joint projects were launched in the EnEff IGHD focus areas. The objectives of these projects include the model of an energy-efficient factory for interdisciplinary technology and applied research, including the building shell and production processes (Eta-Fabrik), the energy efficiency benefits in drive systems by novel coating materials and lubricants (PEGASUS) and the development of highly efficient industrial pumping systems.

The funding area took up diverse new subjects in 2013. These include the energy-efficient, environmentally friendly filtration of large amounts of air in industrial processes and energy conservation in paper production as well as micro process engineering in chemistry, modular equipment for energy efficient production and synthesis, the systemic coupling of energy flows by means of intelligent measuring, control and regulation technology in the machinery or even the energy and resource efficient recasting of large-module gears.

At the international level in the field of EnEff IGHD, Germany participated in the IEA Implementing Agreements "Heat Pumps" (HPP) and "Industrial Energy-Related Technology and Systems" (IETS).

8 See http://www.eneff-industrie.info

Figure 14: Funding for Energy Efficiency in Industry, Commerce, Trade and Services
(See data in Table 3)



2.3 Cross-sector Energy Research

2.3.1 Horizontal Issues and System Analysis

An energy research policy, which complies with the requirements of a globally interconnected energy system with challenging objectives in terms of affordability and environmental impact, requires a comprehensive and detailed orientational knowledge. Preparing technical solutions alone is not sufficient to implement the Energiewende and the accelerated transformation of the energy system. The appropriate political, legal, economic, environmental and social conditions must be created, so that the increasing integration of renewable energies can be ensured without having supply security and social cohesion take a back seat.

In the framework of the BMWi's funding focus area "En:SYS – System Analysis in Energy Research," system analytical work is being funded in the area of method development and technology evaluation. Research projects that were newly approved for this purpose in 2013 include projects in the areas of the potential uses of electric vehicles, the European integration of control electricity balancing markets, profitability analyses for various power storage technologies as well as interdependencies between electricity, heat and gas supply systems. In total, 16 new research projects were approved in 2013 with appropriations of 7.1 million euros. The funding paid out in the funding area of system analysis amounted to around 5.6 million euros (cf. Fig. 15). This includes a total of 36 ongoing projects.

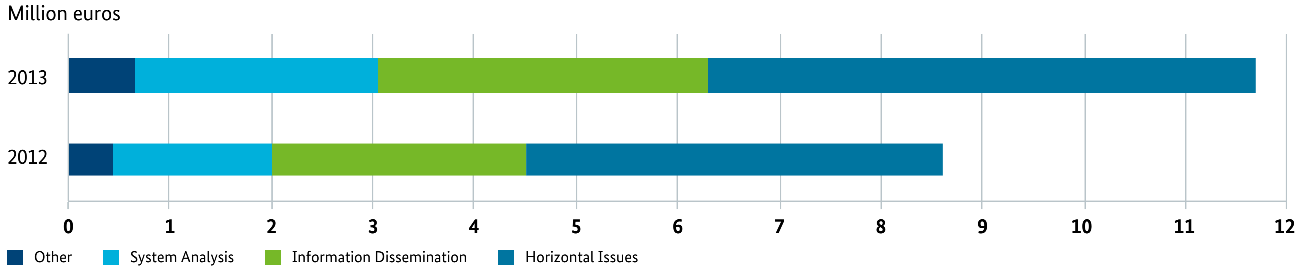
In the BMBF project Energy Systems of the Future, the German science academies aim at combining the interdisciplinary scientific expertise in Germany and at focusing it on the central issues of the Energiewende. Alongside questions of technological feasibility, economic and legal questions as well as those of efficient resource usage are being addressed. Various options for the energy system of the future are being developed from a system-wide perspective. In this way, an orientation framework is provided, which leaves room for different technological and economic options. The project aims to provide possible solutions to address the energy transition and thus contribute to the effective implementation of a secure, affordable and sustainable energy supply. It provides a scientifically sound basis for discussions for society as a whole. The results of the project by the science academies serve as the scientific basis for decision making (science-based policy advice) and flow into the Energiewende Research Forum dialogue platform.

Furthermore, in the field of international cooperation, individual investments were provided by Germany to different parent bodies of the International Energy Agency IEA.

The Energiewende transition to a power supply based primarily on renewable energy sources by 2050 is associated with extensive and complex questions, which flank this conversion process.

The BMU also supported research projects on overarching issues of energy research in 2013. Specifically, projects that received funding deal with cross-sectoral considerations of the Energiewende as a learning system, possibilities for the flexibility of the whole system as well as studies about the challenges of the expansion of renewable energies in the heating market.

Figure 15: Funding for Horizontal Issues and System Analysis
(See data in Table 4)



In 2013, 16 new research projects in the amount of 4 million euros received budget appropriations. The studies on social, ecological and economic framework conditions in the context of promoting cross-cutting issues exceeded the value of the previous year with around 4.6 million euros paid out in 2013 (cf. Fig. 15).

2.3.2 Accompanying Research and Evaluation of Project Funding

For effective and efficient cross-energy research, the view of the German government is that, in addition to promoting individual initiatives, accompanying research for individual funding initiatives is useful to support the interlocking and interaction of funded individual initiatives and to be able to assess them as a whole. The starting point is comprehensive data collection from a large number of research projects.

Accompanying Research on Energy-Optimised Construction

Systematic building analysis is the basis for applied building research. Only with the scientific processing of cross-project topics do the data, facts and experiences of individual projects gain a real significance for research and construction. The results benefit future construction work in new and existing buildings through applied research in selected subject areas as well as through education and training.

The current research topics of accompanying research in energy-optimised construction (EnOB) are:

- Zero energy and zero-emission buildings as models for the national implementation and updating of the European directive “Energy Performance of Buildings”
- Optimised interfaces between buildings and energy networks
- Adaptation of existing buildings to weather conditions in the face of climate change
- Life-cycle-oriented building design
- Achieving a high quality of architecture with high levels of energy efficiency, user-friendliness and thermal comfort
- Operational optimisation of buildings
- Development of simulation techniques for research and teaching.

The funding is done in technical and organisational coordination with other national funding programs, such as the research activities of the BMVI, the pilot projects of the German Energy Agency (dena) and the demonstration projects of the German Federal Environment Foundation (DBU). Project funds from the EnOB accompanying research program, which is subsidised by the BMWi, were disbursed in the amount of 0.81 million euros in 2013.

Accompany Research to Energy Efficient Cities

The planning and implementation of energy efficient neighbourhood concepts is not state of the art today, let alone common practice. This is where the research initiative Energy Efficient Cities (EnEff:Stadt) comes into play. With ambitious demonstration projects in typical urban districts, practical experience is being collected in the usage of new technologies and planning tools as well as implementation management and operations optimisation. The results and conclusions are scientifically evaluated in the framework of accompanying research and are transferable to other projects and sites.

An interdisciplinary accompanying research team evaluates and documents the results. These are made accessible to the professional audience. According to the interdisciplinary nature of the tasks that are needed to solve the energy optimisation of a neighbourhood, other experts are joining in from the areas of energy supply structures, energy storage, planning tools, energy efficient buildings, accounting and measuring, planning procedures, stakeholder participation and socio-economic factors as well as for the transfer of knowledge in the municipal practice. The EnEff:Stadt accompanying research program received 0.94 million euros in 2013 paid out by the BMWi.

Accompany Research to Energy Efficient Cities

The five projects of the winning cities in the BMBF competition “Energy Efficient Cities” are also affiliated with accompanying research, which deals with a research focus on holistic system analytical evaluations, integral planning as well as modelling and model application of administrative structures. In addition, a service accompanying research was integrated into this, which carries out tasks including local case studies analysis and developing tools for the acceptance of services. Other activities of the accompanying research include cross-sectoral analyses as well as supporting the transferability of funded projects to other cities. The BMBF paid out approx. 0.38 million euros in 2012 and approx. 0.26 million euros in 2013 on “energy accompanying research.”

For the service accompanying research, the BMBF provided a total of 0.89 million euros of budget appropriations, of which 0.17 million euros were paid out in 2013.

Evaluation of Energy Efficiency in Industry, Commerce, Trade and Services

On behalf of the BMWi, the Institute for Future Studies and Technology Assessment (IZT) carried out an evaluation of project funding in energy research – here energy efficiency in industry, commerce, trade and services (IGHD) – in the framework of the Fifth Energy Research Programme. In this, 119 project topics with 226 individual project grants, approx. 110 million euros in government funding appropriations and approx. 204 million euros total project costs, were evaluated over a ten-year period.

The main topics with a total share of approx. 70 percent were innovative developments for thermal processes, measurement, control and regulation technologies, new technologies for rational use of electricity and provision of cooling.

The energy-intensive sectors – mechanical engineering, automotive construction, electrical engineering, precision engineering, optics, EBM goods, heat pump, refrigerant, industrial furnaces, the iron and steel industry – were affected by the subsidies. A trend was observed away from projects connected to individual components and towards energy efficiency projects on complex processes and coupled energy flows. The funded innovations typically had the characteristics of demand-oriented energy supply and use, integrative management of material and energy flows, shortening of process adjustment times through the use of information and communication technologies.

The average funding rate (amount of money appropriated by the federal government in relation to total project cost) in this field amounted to 54 percent and slightly decreased over the period under review. Among the subsidised enterprises, 60 percent were made up of small and medium-sized enterprises.

Evaluation Research for Sustainability (FONA)

The BMBF has been subsidising research for sustainable development for ten years and has placed it within its own framework program "Research for Sustainability" (FONA). A third framework program will tie in with FONA 1 (2005–2009) and FONA 2 (2010–2014). Within the framework of the strategic evaluation of the FONA programme, two proposal calls from energy research at the BMBF were evaluated in 2013: the initiatives "BioEnergy 2021" and "Organic Photovoltaics." Each of the measures included an online survey of funding recipients as well as an Audit Day, where the selected projects (eleven from "Bioenergy 2021" and five from "Organic Photovoltaics") were presented to a group of external experts. The results of this process are included in the ongoing update of the FONA program.

2.4 Socially Compatible Transformation of the Energy System

The Energiewende has resulted in wide-reaching consequences for the energy system, as well as for the economy and society as a whole. In the future, energy policy aims to provide energy in-line with current demand and to produce it as environmentally friendly as possible by a significant increase in the share of renewable energies in the energy supply. Therefore, the most necessary measures include expanding supply grids, establishing new techniques of energy supply and storage, as well as coordinating demand and generation by region and time so that the supply remains secure. Social aspects are of great importance to the implementation of this paradigm shift. The design of the energy revolution will only succeed if it adequately reflects the needs and expectations of the population, industry, trade and local authorities – also in regards to issues of participation and justice – as well as the market requirements.

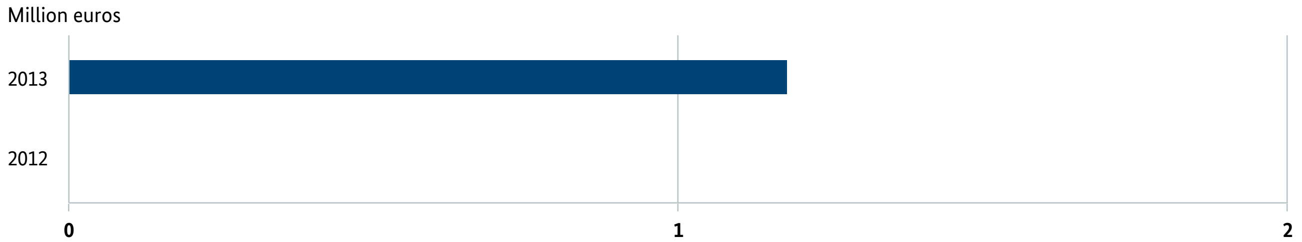
This current social problem area is taken up in the funding initiative "An Environmentally and Socially Compatible Transformation of the Energy System."

The BMBF supported 33 research projects, which are to develop concrete proposals for solutions, with budget appropriations of 30 million euros. The funding amount paid out in 2013 amounted to over 3 million euros (1.18 million euros in the framework of the Energy Research Programme, see Fig. 16). Three research priorities take centre stage:

- The presentation and evaluation of development options for energy systems including economic scenarios
- Analysis of social conditions for the acceptance of the transformation and the active participation by citizens
- Governance of transformation processes including economic instruments

All projects develop recommendations for policy, economy and society. In the sense of trans-disciplinary research, scientists are working together with people with practice experience (e.g. local governments, public utilities and enterprises).

Figure 16: Funding for Socio-ecological Research
(See data in Table 4)



2.5 Fusion Research

Responsible research funding also includes long-term developments in social, economic and technological fields. Thus, the German government within the framework of the Energy Research Programme is following the recommendations of the Leopoldina in continuing fusion research for the security of energy supply in Germany.

Against this backdrop, the German government supports the international thermonuclear research reactor ITER which is under construction at the Cadarache site in southern France. ITER is to be the first reactor that will reach the 500 MW range using fusion power, delivering ten times more energy than is needed to heat the plasma, and therefore it should demonstrate the feasibility of controlled terrestrial energy from fusion processes.

Promoting nuclear fusion takes place primarily within the programme-oriented research at the Helmholtz Association. The Max Planck Institute for Plasma Physics (IPP), the Karlsruhe Institute of Technology (KIT) and the Research Centre Jülich (FZJ) are involved in this program.

Germany has outstanding scientific expertise in the field of nuclear fusion by international comparison. Therefore, it seems advisable to continue nuclear fusion research in order to ensure that this energy source's potential can be evaluated for the future. A world-wide unique infrastructure is available in Germany with large devices like the high-temperature helium loop (HELOKA), the test facility for superconducting components (TOSCA) (both at the KIT), the Tokamak "ASDEX Upgrade" and the stellarator "Wendelstein 7 X," expected to be completed in 2014 (both at the IPP).

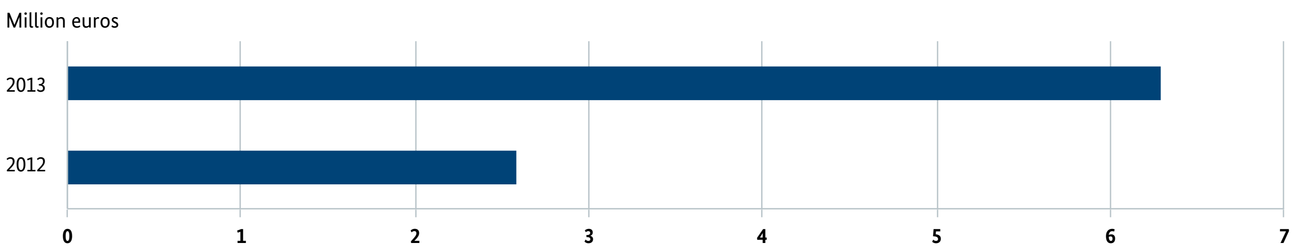
With the aim of benefiting German industrial companies with this expertise and strengthening their international competitiveness in regard to the most technologically challenging jobs in the context of ITER and the *Broader Approach which exceeds it, the BMBF has created a temporary project funding program* (see Fig. 17) with a focus on collaborative projects between research institutes and industry. It will expire in 2017. In 2013, 6.3 million euros were paid out for this topic.

2.6 Nuclear Safety Research

For the operation, decommissioning, and dismantling of nuclear power plants and research reactors, as well as for the final disposal of radioactive waste the highest safety requirements are obligatory. "The advancing state of the art of science and technology" must be maintained according to section 7 of the German Atomic Energy Act. For this aim to be met, lawmakers have entrusted a prominent role to research and development.

In order to fulfil the objective of this directive, the BMWi performs strategic investments in research and development by project funding of nuclear safety and disposal research. The project funding aims at providing the scientific basis for further development in science and technology and finally contributes to the design, development and maintenance of the scientific and technical competence. This is especially true considering the backdrop of Germany's decision to phase out nuclear electricity generation by the year 2022, because nuclear related applications are still needed in industry, research and medicine even beyond the remaining lifespan of nuclear power plants in Germany. Thus, a high degree of professional competence and the availability of advanced evaluation

Figure 17: Funding for Project-related Fusion Research
(See data in Table 4)



methods remain an essential prerequisite for a scientifically sound safety assessment of nuclear power plants and final disposal systems in Germany and abroad.

As a contribution to maintaining competence and competence enhancement, the BMBF is flanking the BMWi's research support with the areas of nuclear safety and waste disposal research and, in addition to this, with radiation research with the aim of promoting young researchers. Based on the targets of the BMBF promotion concept from 2008, "Basic Energy Research 2020+," these activities are promoting the inter-networking of science and industry and are bringing together energy-related basic research with application-oriented work.

2.6.1 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 worldwide through international cooperation.

The project-funded reactor safety research is predominantly based on subject areas which were classified as a priority by an evaluation commission appointed by the BMWi. In 2013, the priority research topics were re-evaluated by the Alliance for Competence in Nuclear Technology in the context of Germany's decision to phase out the generation of electricity from nuclear power by 2022. These were published in the "Nukleare Sicherheitsforschung – Neuorientierung an aktuellen energiepolitischen Rahmenbedingungen" (Nuclear Safety Research – Reorientation to Current Energy Policy Framework Conditions) report[9].

The BMBF supplements BMWi research funding with projects for the training of young scientists, where scientific basics in the field of reactor safety research are broadened according to the BMWi's funding priorities.

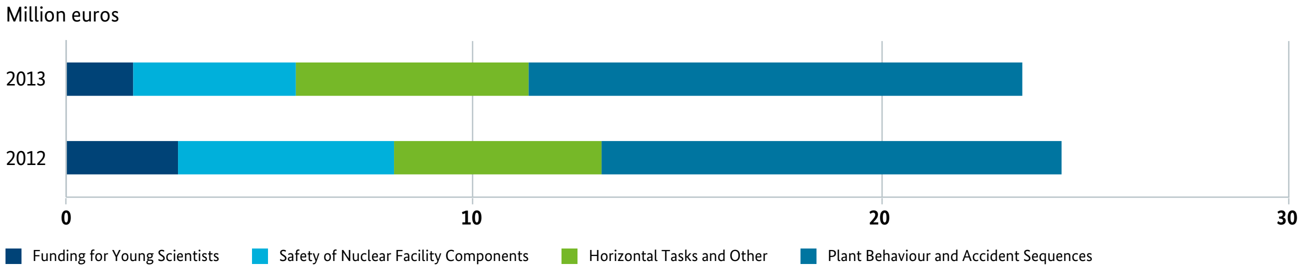
The BMWi's research contributed significantly to the expansion of knowledge and improved assessment of the level of safety at nuclear installations. With respect to analyses of plant behaviour under accident conditions this is for example highlighted by investigations into the formation of zinc corrosion products during sump operation in case of a loss of coolant accident. Results have been presented to the German reactor safety commission and their applicability to real plant conditions is currently evaluated. In the set of topics regarding safety and integrity of structures and components of nuclear facilities, a new test facility (drop tower) was completed to study of the behaviour of reinforced concrete components under shock loading by impact tank. This is relevant for the analysis of loads that may occur during events such as a plane crash.

Regarding the newly initiated projects in 2013, the fifth phase of the experimental program that should be particularly emphasised is "Thermal-hydraulics, Hydrogen, Aerosols and Iodine" (THAI). It consists of single and multiple compartment experiments on fission product and hydrogen behaviour in the containments at nuclear power plants in order to obtain data for the validation of national and international incident codes. A consistently high level of interest is reflected in numerous international collaborations that reflect the high quality of the test results.

Germany participates in international multilateral research projects under the auspices of the OECD/NEA in the framework of the BMWi's project-funded reactor safety research. This includes participation in the "BSAF" project, during which research organisations from countries with relevant expertise in the field of reactor safety simulate the sequence of events for the reactor incident in Fukushima with the assistance of system codes. It aims at enabling the most reliable statements about the condition of the damaged plant, which will be also useful during the pending clean-up and dismantling work. Germany is involved in the project with system codes, which were developed by the Reactor Safety Research Program using BMWi subsidies.

9 Available in German only.

Figure 18: Funding for Reactor Safety Research
(See data in Table 5)



In the framework of BMBF basic research, junior researcher funding measures on topics of reactor safety research were carried out. In 2013, these included, for example, studies on passive containment cooling systems and uncertainty analyses for source term from fission products. They were introduced in the integral evaluation and recommendation of emergency measures, which was discussed against the backdrop of the events in Fukushima (WASA-BOSS). Overall in 2013, the BMBF promoted 33 doctoral students, as well as 10 other young scientists (graduate students, master's students).

Research projects in the field of reactor safety research received a total paid out funding of 23.4 million euros in 2013 (see Fig. 18). Of these, the BMWi appropriated 21.8 million euros of budget commitments and the BMBF 1.6 million euros.

2.6.2 Nuclear Waste Final Storage and Disposal Research

The project funding in the area of decommissioning/disposal research is being led by the BMWi. The funding activities are geared programmatically to the regularly updated BMWi funding frameworks on research and development work about the final disposal of radioactive waste. Application-oriented, location-independent research and development projects are supported for all host rocks relevant to Germany (rock salt, clay and crystalline rock). Research and development activities towards the expansion of knowledge on final disposal concepts, final disposal technology and safety evidence will be significantly subsidised. Nuclear waste final disposal research refers to the topic areas of *final disposal systems, system behaviour and system descriptions, horizontal issues related to the final disposal and nuclear material monitoring*. Some projects are dealt with in international collaborations (Seventh EU Research Framework Programme, foreign underground research laboratories).

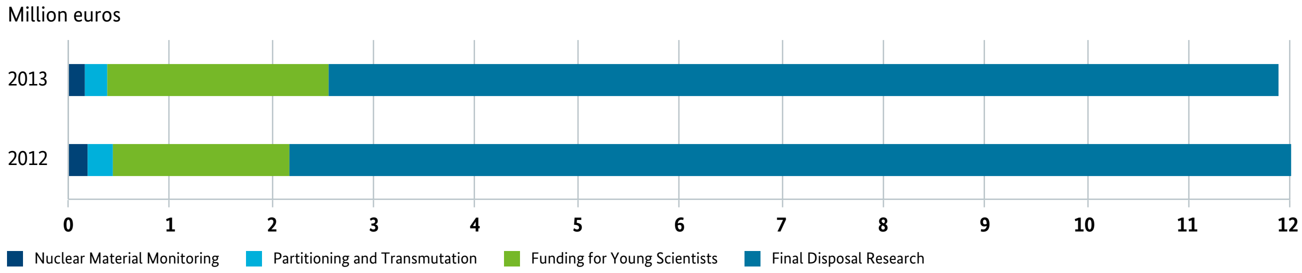
With the change to the legal framework to the site selection law and the associated restarting of the final disposal repository search, other research and development needs have emerged including the in-depth investigation and characterisation of all potential host rocks, methods of site exploration and the impact of extended interim storage times of waste materials and their containers. These aspects will be taken into consideration particularly in the next BMWi funding framework (presumably for the period 2015–2018).

In the subject area *final storage systems*, projects on the evaluation of final storage concepts are carried out based on scientific-technical and safety analysis aspects. Five new projects were approved in this area in the year 2013.

The subject area of *system behaviour* and *system description* includes studies on the modelling of the geomechanical, geochemical and thermo-hydromechanical behaviour of host rocks and the processes taking place within them. Furthermore, projects are dealing with the description and simulation of the possible development of a final storage system within the framework of the long-term safety analysis. Five new projects were approved in this area in the year 2013.

The topic area *Querschnittsaufgaben mit Bezug zur Endlagerung* (horizontal tasks related to final disposal) and the study on the opportunities and risks of partitioning and transmutation (P & T) of highly radioactive waste, which was co-financed by the BMWI and BMBF and which involved the technical and scientific aspects and social implications of a possible application of P & T, were completed.

Figure 19: Funding for Nuclear Waste Final Storage and Disposal Research
(See data in Table 5)



The BMWi project funding also takes into account the topic of *nuclear material monitoring*. This especially problematic topic requires research and development work on conceptual, technical-methodical and political institutional issues. Due to the global importance of the subject, work is embedded in research networks that are connected with multinational cooperations (Euratom, IAEA). A new project was started in the year 2013.

The research and development topic areas of BMWi project funding on waste storage / final disposal research are supported by research and development work on nuclear safety research funded by the BMBF. The scientific work of one national joint research project assigned to the research field *Final Disposal System*. All of the research carried out in this joint project aims in assessing the stability of ceramic matrices for the immobilisation of long-lived radionuclides by their incorporation into these matrices (conditioning). The subject area of *system behaviour and system description* includes projects, which examine the geochemical processes in the near-field of final disposal. In this area, a focus of research is on the quantum chemical modelling of radiochemical and radio-geochemical processes. The joint research project "ImmoRad" studied the interaction of actinides and fission products with repository-relevant minerals on the atomic scale in order to understand the mechanism of surface processes such as retention mechanisms. This understanding finally allows the extrapolation of radionuclide behaviour in a geochemical environment over long periods of time. Currently, another joint project ("f-Kom") is dealing with studies into the basic understanding of the selective complexation of f-elements. These studies contribute to the characterisation, sorting and separation of radioactive materials. The research activities thus flank the BMWi's subject area of *"Querschnittsaufgaben mit Bezug zur Endlagerung."* The BMBF paid out 2.2 million euros to a total of 23 individual projects in 2013 (see Fig. 19).

2.6.3 Radiation Research

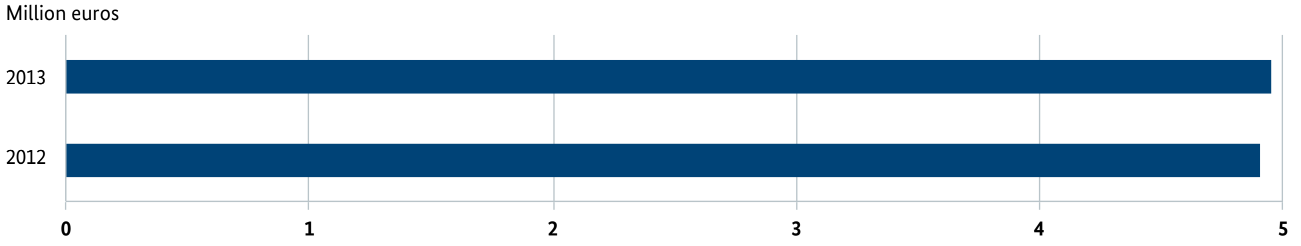
An emphasis of the BMBF's funding in nuclear safety research is in the area of radiation research. Research activities are conducted in this area in coordination with the "Competence Network for Radiation Research" ("KVSF – Kompetenzverbund Strahlenforschung"), which was founded in 2007 as an association of universities and research institutions active in this field. The network wants to promote and maintain scientific expertise in radiation research. The funding is arranged in coordination with the BMUB.

In the field of radiation research, 96 projects were approved and in total approx. 49.5 million euros were appropriated for radio-biological, radiation medicine and radio-ecological issues between 2008 and 2013 (see Fig. 20). The key issues of funding are radiation quality, radiation sensitivity, the dose-to-effect relationship, biological targets and the characterisation of radiation exposure.

In terms of radiation quality, the primary role of UVA rays regarding telomere damage is being studied as well as the role of antioxidant defence and cellular senescence in UV-induced carcinogenesis. Another focus is the study of the damage potential of radionuclides.

In the field of radiation sensitivity, researchers use, for example, epidemiological studies to identify gene variants, which have an increased individual sensitivity to radiation-induced acute and long-term damage by their

Figure 20: Funding for Radiation Research
(See data in Table 5)



impact on the maintenance of genomic stability and are also responsible for a modified radiation sensitivity of tumour cells.

The studies in the area of dose-to-effect relationship are devoted to determining the radiation dose on the basis of radiation-induced gene expression changes, because the compiling of gene expression data is less time consuming and expensive than traditional methods and this research is not limited to specific tissues or cell types.

The research on biological targets focuses on shedding light on primary radiation effects and the repair of DNA damage at the molecular level in order to gain a better understanding of the basic effects of radiation on the cell. The goal is to be able to make predictions regarding the effect of densely ionising radiation, as well as provide information on possible ways to intervene in the effects of radiation.

In the area of characterising radiation exposure, studies are funded on the topics of the spread of radionuclides in air, water and soil, the transport of radionuclides in plants, the validation of biokinetic metabolic models and radiation exposure by natural radionuclides. The overall objective is to increase knowledge and expertise in the field of radio ecology and improve the assessment of the radiation exposure to people via the different paths of exposure.

3. Institutional Energy Research

The Helmholtz Association of German Research Centres is Germany's largest scientific organisation with 37,148 employees and an annual budget of around 3.8 billion euros. It is devoted to important issues that are relevant for the medium to long-term transformation of energy systems and the implementation of the Energiewende in the research area of energy. In the current second period of programme oriented funding, the participating research centres are working together on the five following research programmes (see Fig. 21):

- Efficient energy conversion and use
- Renewable energies
- Nuclear safety research
- Nuclear fusion
- Technology, innovation and society

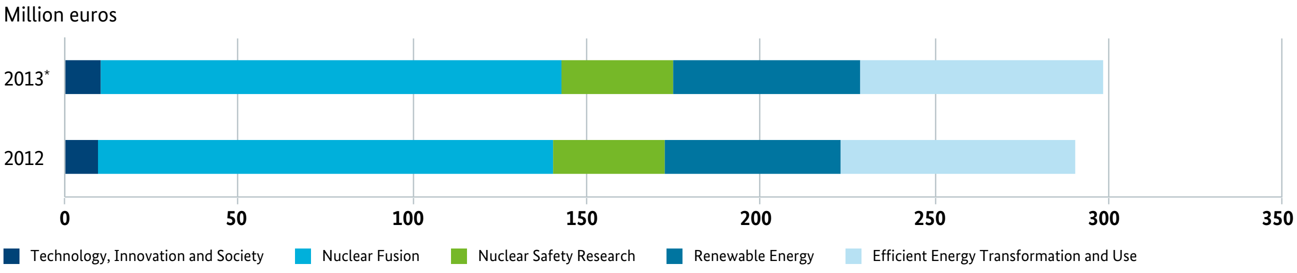
An important strategic milestone last year was the preparation for the third period of the *Programme-oriented Funding* (PoF-III), which will begin in January 2015. For this, an umbrella paper of the research area was created on the basis of the research-political requirements. This paper elaborates on the new program proposals and coordinates the research centres. In 2014, these proposals are evaluated by an international expert commission. The result provides the basis for funding recommendations in the next funding period 2015-2019. In doing so, the research area of energy will be restructured with respect to the current requirements of the Energiewende and thematically expanded. In this way, for example, the program "Storage and Cross-linked Infrastructures (SCI)" and the program "Wind Power" will be reorganised.

Content-wise, the third period of program-oriented funding is already being prepared by the revising of so-called *portfolio topics*. The research area of energy is processing the portfolio topics *Helmholtz Initiative for Mobile and Stationary Energy Storage Systems, Gas Separation Membranes for Zero-Emission Fossil Power Plants, Electrochemical Storage in a Systemic Perspective – Reliability and Integration, Umweltfreundliche Bereitstellung heimischer Energieträger aus Georessourcen (Environmentally-friendly Supply of Domestic Energy Sources from Georesources)* and *Materials Research for the Future Energy Supply*. Also to be mentioned is the portfolio topic *sustainable bioenergy,* which happens to be included in the research field of "key technologies".

Of particular relevance is the horizontal issue "Materials Research for the Future Energy Supply," which was highlighted in the research policy guidelines. Even an HGF Senate committee took this into account in 2012 when classifying the strategic expansion investment for the "Helmholtz Energy Materials Characterisation Platform (HEMCP)" as a priority measure and recommending it for funding. The implementation of investment measures worth around 40 million euros started in 2013. At the research centres in Jülich, Berlin, Dresden, Karlsruhe, Hamburg, Geesthacht and at the German Aerospace Center (DLR), modern equipment and infrastructure is being provided in order to obtain temporally and spatially resolved three-dimensional information about structural, electronic and chemical properties of materials for energy-economic applications in manufacturing and operating conditions (in-situ methods). The investment measure fits into the existing research infrastructure – in particular the large devices, such as the electron synchrotron BESSY at the Helmholtz-Zentrum Berlin.

The cooperation within the HGF but also with universities in strategically important areas was strengthened last year with the decision to establish two new **Helmholtz Institutes** in the field of energy. In August 2013, the Helmholtz Institute Erlangen-Nuremberg (HI-ERN) for renewable energy was founded. The new Institute intensifies the existing cooperation between the HGF research centres in Jülich and Berlin with the Friedrich Alexander University in Erlangen-Nuremberg. Material research for solar technologies and the production of hydrogen from renewable energy sources are at the heart of the work. In October 2013, the Helmholtz Association senate decided to establish a Helmholtz Institute in Münster (HI-MS), which opened in 2014. The Research Centre Jülich is involved in the institute alongside the University of Münster and the Rheinisch Westfälische Technische Hochschule in Aachen (RWTH). The main focus will be electrochemical energy storage systems. With its focus on electrolytes and their ionic behaviour, the new institute complements the Helmholtz Institute in Ulm, which was founded in 2011. The University of Ulm and the Center for Solar Energy and Hydrogen Research in Baden-Württemberg (ZSW) are involved in this alongside Karlsruhe Institute for Technology (KIT) and the German Aerospace Center (DLR).

Figure 21: Topics of the Helmholtz Association of German Research Centres
(See data in Table 6)



* preliminary data

In addition to the four Helmholtz Energy Alliances, which have existed since 2012, an additional energy alliance, the alliance "Technologies for a Future Energy Grid," was launched early in 2013. The Karlsruhe Institute of Technology and the Research Centre Jülich are involved as partners from the HGF. They are cooperating with the Technical University of Darmstadt, the Technical University of Dortmund and the RWTH Aachen University. From the HGF's initiative and networking fund, this alliance was funded with 3.2 million euros in the years 2013 and 2014 and supplemented by additional funds from the partner. The alliance works on grid-related issues arising from the fluctuating power supply of renewable energy sources. Smart distribution grids, hybrid transportation by the integration of technologies for high-voltage direct current transmission and also the integration of storage in the grid infrastructure play an important role.

The first prerequisite for excellent research results are outstanding researchers in the field of energy research. Therefore, the HGF already enacted a **recruitment initiative** in 2012, which provides funding for W3 and W2 positions in the energy sector as joint appointments by HGF centres with universities. By the end of 2013, seven appointments were made or are in the process of being implemented in relation to energy.

4. Other Funding Activities

4.1 Research Funding from the German States

The energy research-related subsidies from the German states are an integral part of total state expenditure for energy research in Germany. On behalf of the BMWi, Project Management Jülich (PtJ) already carried out a study on the topic of the "Expenditures by the German States for Non-nuclear Energy Research" for the years 2003 and 2006. To continuously examine the development of national energy research activities together with its technology-specific emphasis, an annual state survey has been conducted since 2008[10]. The energy policy trends at the state level, which were apparent in the previous time series, are also incorporated into the federal-state discussion. This is held annually in the framework of the Coordination Platform for Energy Research.

The basis for the survey is an enquiry into the figures on energy research and development (including demonstration projects) and the associated funding programmes. Financial expenditures for market launch or energy conservation programs as well as other investment aid are not relevant for this survey.

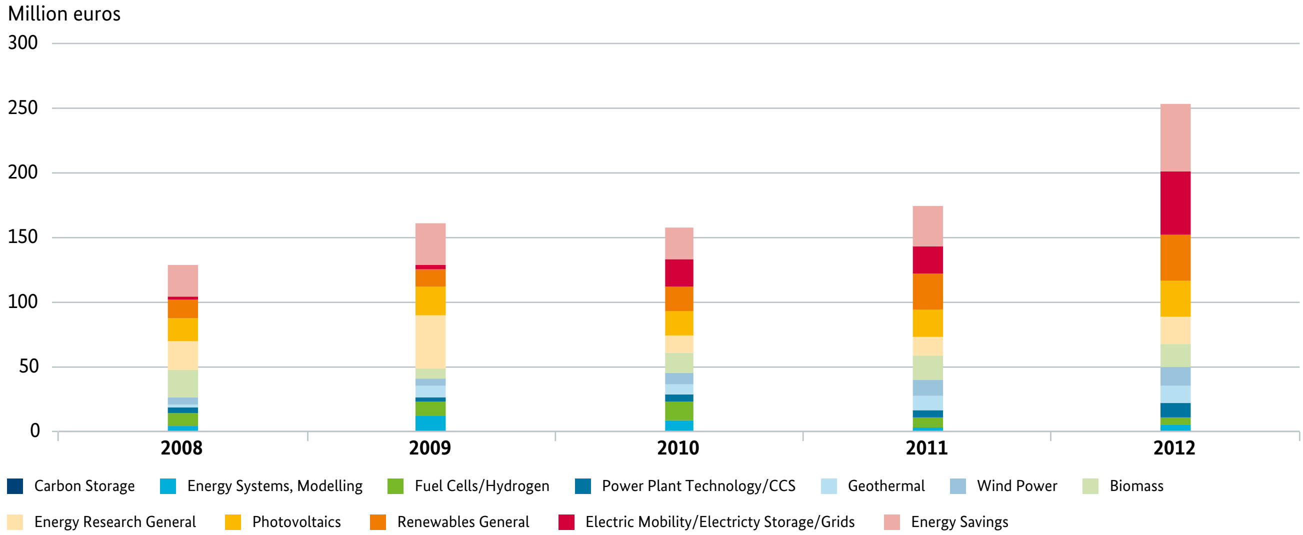
The energy research of the federal government differentiates between project funding and institutional funding. Thus, a separate survey of both grant instruments is carried out in the state analysis as well. The direct project funding is handled through funding programs and initiatives, and thematically reflects the technology policy for energy research in the individual German states. The institutional funding of state-based research institutions can in turn be maintained by the state alone or jointly with the federal government. Project funding and institutional funding are examined together within the present study.

State research programs can also be partially financed by the European Regional Development Fund (ERDF). For this, a fixed contribution by the state is necessary. With regards to this financing instrument, only the relevant funds invested by the state have an effect on the survey.

A significant increase was recorded in the total expenditures of the German states for non-nuclear energy research between the years 2008 and 2012 (see Fig. 22), which is approximately equal to the growth scenario of the federal government in the same period.

The survey covers the sector renewable energy as individual technologies (divided into biomass, geothermal, photovoltaics, wind power and general renewable energies).

Figure 22: Expenditures by the German States for Non-nuclear Energy Research 2008 – 2012
(See data in Table 8)



10 This report covers the German states' expenditures in the area of energy research from 2008 to 2012. The figures for 2013 are not available yet and will be the subject of the next governmental report on energy research.

However, in this summary they are shown grouped together. As expected, they constitute a research focus that is an essential pillar in the Energiewende process, and the financial expenses related to these almost doubled on the side of the states' governments between 2008 (61.2 million euros) and 2012 (108.5 million euros). Within renewable energy research, photovoltaics and biomass are the technological priority areas for research funding by states.

The planned boost in the proportion of renewable energy for electricity generation has simultaneously raised the requirements to adapt to an increasingly volatile and decentralised energy supply. An energy supply focused on regenerative energy sources implies the growing use of thermal, material and electrochemical energy storage in the medium to long term, and, at the same time, it requires the reliable operation of high-performance grids. In addition to the federal government's funding priorities on energy storage and electricity grids, the research area of electric mobility/power storage/grids is mirrored at the state level and is experiencing the strongest growth financially between 2008 and 2012. Even though this research area still formed a rather niche technology in 2008 with only 1.6 million euros, in the meantime, it has united the essential key technologies for the intended transformation of the energy supply system and was already being funded with 49.3 million euros by the federal government in 2012.

Furthermore, energy conservation and efficiency has established itself as an essential area of funding in the German states. Energy conservation encompasses the generation, conversion, transport and the final consumption of energy and has always been in the research focus of the states' technology funding. As "efficient energy use," it has been an integral part of national energy policy on all levels since the introduction of the first energy research program "Energy Research and Energy Technologies" in 1977. The wide array of the research funding for energy efficient technology is reflected in the states' expenditures: With over 50 million euros, funding for energy conservation is the most funded research field after renewable energy.

System-analytical studies and energy policy scenario analyses form the focus of research in the area of energy systems/modelling. This plays a relatively minor role in energy policy, but it is receiving a new impetus through the increasing implementation of socio-scientific aspects, systemic studies of energy networks and new approaches to modelling.

A steadily growing share of renewable energy in electricity generation presents new challenges to conventional power plants in terms of load flexibility and grid stabilisation and simultaneously requires the synchronisation with other load balancing technologies (such as smart grids). System integration and flexibility of power plant processes while simultaneously increasing efficiency are currently the most strategically important funding areas of power plant technology. This has gained importance in recent years and received almost 12 million euros in funding from the German states in 2012. Included therein are also research activities on carbon capture and storage, which deal mainly with monitoring procedures and security concepts, and make up only a marginal percentage due to the massive public resistance to deploy this technology.

The extent of funding research for fuel cell/hydrogen technology is slightly declining at a high level. Due to their high energy density and the achievable high levels of efficiency, the efficient use of fuel cells is opening up for both stationary and mobile applications. In combination with other energy technologies, the use of electric surplus energy, especially from renewable energy sources, appears to be well suited for electrolytic production of hydrogen, the fuel used in fuel cells.

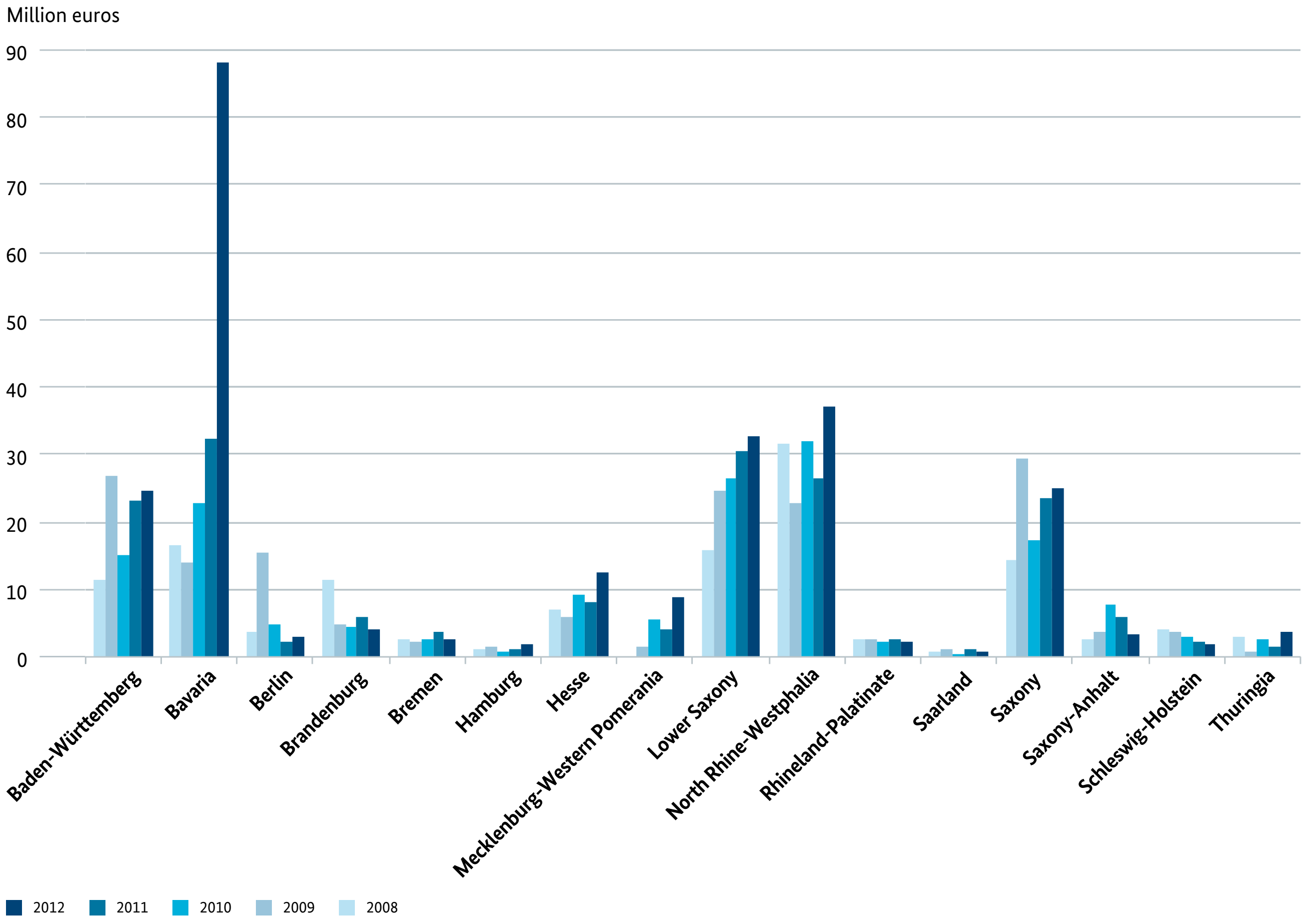
The information in this survey subsumed as "general energy research" refers to expenditures that cannot be further differentiated by the responsible state ministries or that cannot be assigned to a specific energy technology.

The reorientation of Germany's energy policy after the events in Fukushima in March 2011 also resulted in a new emphasis on the research priorities at the states' level, particularly in states with a high percentage of nuclear energy in electricity consumption. Therefore, in Bavaria, for example, an expert commission was charged with developing the framework concept "Bavarian Alliance for Energy Research and Technology." This is set for a ten-year period (2012-2021) and has the key objective of increasing renewable energy sources to 50 percent of electricity generation by 2022. Additional funding for this purpose dominates the trend graph for expenditures by the states on non-nuclear energy research (see Fig. 23).

In addition to Bavaria (+55.8 million euros), North Rhine-Westphalia (+10.7 million euros), Mecklenburg-Western Pomerania (+4.8 million euros) and Hesse (+4.5 million euros) recorded a significant increase in their subsidies, while expenditures are on decline in Saxony-Anhalt (-2.6 million euros), and Brandenburg (-1.8 million euros). A detailed review of the individual states' expenditures on energy research is provided in separate annual reports. These reports can be found on the website of Project Management Jülich for the years 2006, and 2008 up to and including 2012[11].

The present time series analysis highlights the fact that the promotion of non-nuclear energy research by the individual states represents a key pillar of national energy research in Germany. The objectives postulated in the federal government's Sixth Energy Research Programme are fundamentally reflected in the energy policy priorities of the individual states. State-specific priority areas are characterised by political and economic interests as well as geographic framework conditions, which results in a much differentiated image that complements the federal governments' policy.

Figure 23: Expenditures for Non-nuclear Energy Research for each German State 2008 – 2012
(See data in Table 7)



11 See http://www.ptj.de/geschaeftsfelder/energie/laenderbericht-energie

4.2 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. In this context, European funding for energy research aims at transforming the current energy system in Europe into a sustainable, competitive system, which will also guarantee a secure energy supply. The SET-Plan[12] complements this objective by specifically striving for the accelerated expansion and proliferation of low cost and low carbon technologies.

The Seventh Research Framework Programme (FP7) expired in 2013. During the entire period of the FP7, 2.3 billion euros were made available for energy research in the non-nuclear field.

Horizon 2020

The successor to the FP7 program is "Horizon 2020," which started in 2014. This is making funds available in the amount of 80 billion euros for cooperation projects over a period of seven years. The topic of non-nuclear energy research is located in the activity field "societal challenges" as the topic field "secure, clean and efficient energy supply." It includes research and development activities as well as the accompanying market preparation measures. A budget for this has been earmarked in the amount of 5.8 billion euros. The first calls for the years 2014 and 2015 in the topic area of "safe, clean and efficient energy supply" relate to the following research and innovation priorities:

- Reduction of energy consumption through sustainable and intelligent utilisation by consumers and producers
- Development the power supply through renewable energy including heating/cooling
- Energy system flexibility through improved storage technologies
- Alternative fuels
- Decarbonisation in the use of fossil fuels
- A modern pan-European electricity grid
- Energy, transport and communication solutions for smart cities and municipalities

Review of the FP7: Successful participation by German applicants[13]

570 partners from Germany, thus 23 percent of all applicants, successfully participated in the calls for non-nuclear energy research in the time period under review (2007 to 2013). They will make use of 282 million euros of Commission research funding until the end of each project's duration. This is equivalent to 15 percent of the total estimated funding for all countries participating in the FP7 calls[14] (see Fig. 24). In comparison, Germany is well in the lead with this result, followed by Spain (13 percent), Italy (10 percent) and France (9 percent).

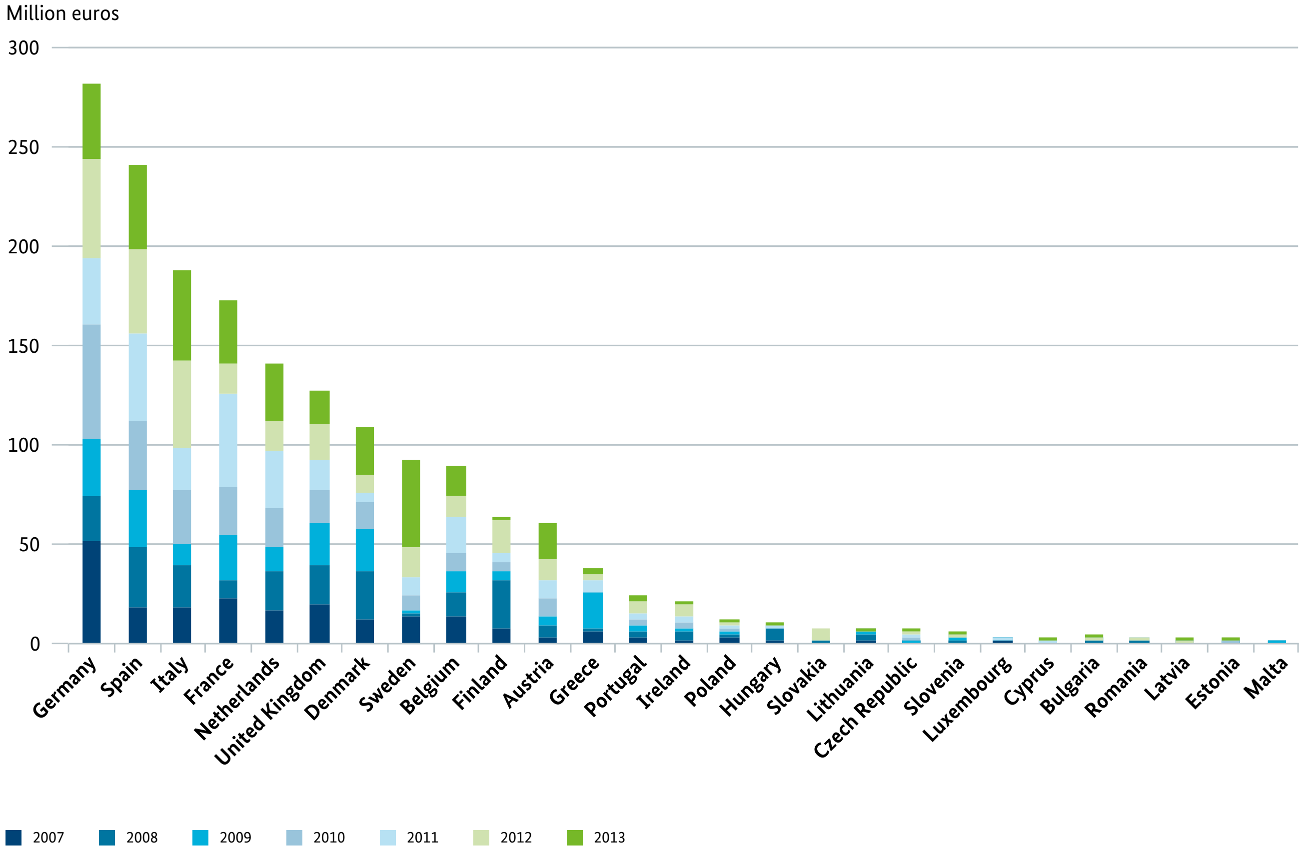
German participants are involved in more than 76 percent of all successful projects with at least one partner involved. They cooperate frequently with partners from Spain, Italy, France, the UK and the Netherlands. About 17 percent of all projects are coordinated by German project partners.

12 Strategic Energy Technology Plan (2008), see http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm

13 The information is based on the funding totals, which have been recommended after evaluation by the European Commission, for successful, ie fundable proposals. ERA-Net-Calls (2007, 2011, 2012, 2013) and Ocean-Calls (2010, 2011, 2013) were not included in the analysis for reasons of comparability. The German participation to these calls was low.

14 In addition to the EU-27 countries, a further 44 countries were involved, which accounts for around 10 percent of the total of funding; among these are most notably Switzerland, Norway, Turkey and Israel.

Figure 24: Distribution of financial subsidies to EU countries in the FP7 in the field of non-nuclear energy research for the years 2007 – 2013
(See data in Table 9 and Table 10)



Private enterprises rank at the top among the successful German applicants: nearly half of all partners (selected for their participation) belong to this group of participants. Nearly 40 percent are small and medium-sized enterprises (SMEs). Therefore, even at 50 percent, the largest share of EU funds for German participants is appropriated to the private sector, 24 percent of this goes to SMEs.

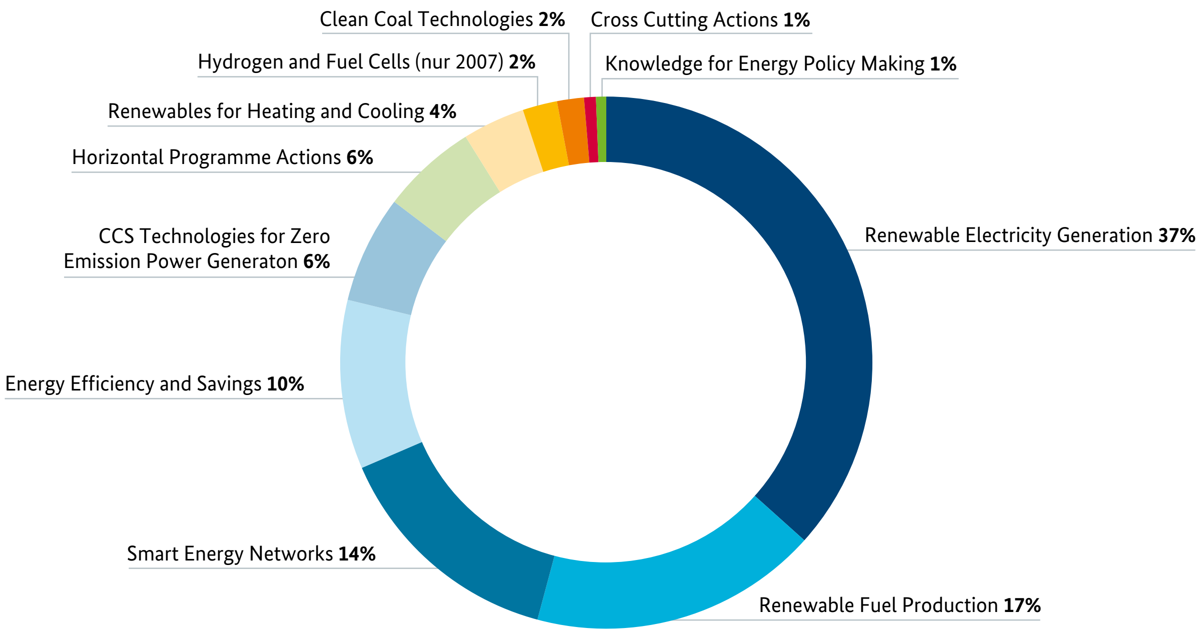
Nearly 50 percent of the successful participants come from research institutes and universities. They receive a total of approx. 46 percent of the subsidies. Public administration plays only a minor role as a partner in research projects.

Thematic Priorities for EU Research Funding

The annual energy work programs of the FP7 consisted of various activities. Their spectrum however remained unchanged over the period of FP7, but they were furnished with financial resources annually in varying amounts depending on the respective topics. Individual calls to submit project proposals were also gears towards selected key activities.

The funding percentages for successful German project proposals are divided into all 11 activity fields of FP7 calls (see Fig. 25). “Renewable Energy Sources” (activities: renewable electricity generation, renewable fuel production, renewables for heating and cooling) account for the highest subsidies by far compared with each year of FP7’s duration. It is 58 percent in total. “Smart power grids” and “energy efficiency/energy savings” follow in second place at a considerable distance with a total share of 25 percent (activities: smart energy networks, energy efficiency and savings).

Figure 25: Distribution of Project Funding for German Participants in Activities in the Field of Non-nuclear Energy Research, 2007 – 2013
(See data in Table 11)



The funding portion for the activity field “renewable energies” for project proposals from German SMEs is even higher at 60 percent. This similarly affects “smart power grids and energy efficiency/energy savings” at 31 percent.

SMEs are also very well represented in the mentioned activity fields. They represent 60 percent of applicants for “renewable energies” and 40 percent of applicants for “smart power grids” and “energy efficiency/energy savings.”

The activity in “electricity generation from renewables” covers the topic areas photovoltaics, biomass, wind, geothermal, solar thermal power plants, oceans, hydropower as well as horizontal issues. German applicants benefit above average through their participation in successful project proposals, which amount to 20 percent of European Commission subsidies and are clearly ahead at the top of the leader board.

Examples of Subsidised Projects

The size of German interest in the topic of “energy” in the FP7 can be seen in some of the research projects which were carried out by the end of 2013.

During the period of the FP7, 35 projects were completed with German coordinators. These research projects had a duration of between one and five years. In total, over 350 organisations were involved. Roughly one-third of these were German partners. For these 35 research projects, the EU made more than 100 million euros in funding available, of which about 45 percent went to German organisations. The topics covered in the projects are wide-ranging as well.

The projects NANOHY, FLYHY and HYCYCLES dealt with research in the field of material properties and qualification for the production and storage of hydrogen. DECODE had the objective of increasing the service life of fuel cells for automotive applications.

Numerous research projects were subsidised in the field of photovoltaics. For example, the projects ROD-SOL and HIGH-EF in materials research worked on the utilisation of nanomaterials and processes for solid-phase crystallisation. A few other projects dealt with the development of elements and systems for product launch in the form of prototypes and demonstrations of manufacturing processes (ULTIMATE organic NICOL, SOLASYS, HIPOCIGS, 20PLπS, R2M-SI, ASPIS).

Other projects in the area of renewable energy, in which German institutions participated, dealt with topics of wind power (onshore and offshore), geothermal and biomass. Thus, for example, the project "7-MW-WEC-by-11" focused on the demonstration of cost-effective large wind farms with the world's current most powerful wind turbines in the range of 7 megawatts. In the framework of the joint project Wingy-PRO, scientists engaged in the development of a novel synchronous generator with transverse flux management and its subsequent integration into an existing wind turbine. In the field of offshore wind, current and wave power, the project ORECCA pursued the goal of knowledge sharing by promoting pan-European scientific cooperation and knowledge transfer between stakeholders in politics, industry and research. As a result of this project, a platform was created for pan-European knowledge transfer and a road map was compiled with recommendations for technology funding with a focus on synergies between the different energy conversion technologies as well as their development opportunities and possible existing barriers. The research projects ENERCOM, OPTFUEL, PROPANERGY and RECOMBIO dealt with the production of biomass and the polygeneration of electricity, heat and fuel. In addition to the projects with a research and demonstration character, the German partners have the following focus areas within the framework of the FP7: The creation of a platform for monitoring and generating synergies between the platforms/stakeholders (BIOFUELSTP); the identification of opportunities and research needs in Latin America (BIOTOPE) and the harmonisation of the biomass resource assessment for Europe and adjacent regions (BEE).

Furthermore, several projects were financed for energy savings (NanoBAK), including with a consideration for the building sector (HESMOS and EEBGUIDE). These projects followed different approaches, ranging from the use of new materials to the use of an ICT platform for simulation and management. Other projects worked on the development of standards, the ICT communications infrastructure (W2E), the development of infrastructure models for the distribution of renewable energy sources (MIRABEL), the development of grid monitoring concepts (ICOEUR), as well as the production of an analytical framework to cope with the mass introduction of electric and plug-in hybrid vehicles (G4V).

The Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI) in the EU Framework Programme for Research

EU research in the field of fuel cells and hydrogen technologies has been driving forward the Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI) since 2008. For research and innovation funding, which is implemented by the agency FCH Joint Undertaking as a public-private partnership (PPP), a budget of 940 million euros was allocated for the duration of the programme between 2008 and 2013, whereas the duration of the projects must end by 2017 at the latest. The public funding came from the FP7 and amounted to 470 million euros. The rest was raised by private companies as their own contributions. The priority areas defined by the Multi Annual Work Programme were transport and hydrogen infrastructure refuelling (34 percent), hydrogen production and supply (11 percent), stationary applications and combined heat and power (35 percent), market launch measures (13 percent) and cross-sectoral activities (7 percent).

The content of each of the calls defined the Annual Implementation Plans. The FCH JU opened the support for cooperation projects with the first calls for proposals in October 2008. It was followed by other calls for tenders every year until 2013. Their budgets were between 27 and 118 million euros (two calls for tenders in 2013).

Between 2008 and 2012, FCH JU projects were financed with a total volume 342.9 million euros, of these 86.6 million euros was apportioned to Germany (25.3 percent). The Federal Republic of Germany coordinated 26 out of a total of 131 projects in the aforementioned period.

From 2014, this initiative will be renewed with FCH 2 JU. The proposed budget for the period 2014–2020 is 1.33 billion euros. The EU will provide half and the other half will come from project partners. The activities are focused on two pillars: Technologies for transport and technologies for energy systems. Storage technologies based on hydrogen have be declared the leitmotif of the activities.

5. Tables

5.1 Funding in the German Government's Energy Research Programme

For the national subsidies, the following tables represent the money paid out during the year (actual outlays) in each budget year as defined in the OECD Frascati Manual. Provided that funds are repaid, this is taken into account retroactively in the year of the disbursement, so that minor deviations in individual topic areas may arise in comparison to the 2013 edition of this report.

Table 1: Overview of Topics in the Sixth German Energy Research Programme

Funding area	Actual outlays in million euros							
	2006	2007	2008	2009	2010	2011	2012	2013
Energy efficiency	110.34	133.95	151.55	189.31	206.13	215.14	239.06	296.64
Renewable energy	120.23	126.47	152.86	202.01	210.61	220.90	258.85	298.10
Nuclear safety	54.33	57.58	62.59	70.41	71.93	73.03	74.74	75.62
Fusion	114.41	121.52	125.58	142.65	131.03	137.44	133.10	138.72
Total	**399.31**	**439.52**	**492.58**	**604.37**	**619.71**	**646.51**	**705.75**	**809.09**

Table 2: Actual outlays in the Field of Energy Conversion

Funding area	Actual outlays in million euros	
	2012	2013
Photovoltaics (incl. other programs)	**67.08** (85.69)	**63.59** (81.16)
Crystalline silicon	30.40	30.51
Thin film technologies	15.33	12.69
Basic research (incl. other programs)	15.62 (34.23)	14.87 (32.44)
Other	5.73	5.53
Wind Power	**38.42**	**52.57**
Wind farm development	2.62	15.07
Onshore	0.62	0.51
Offshore	3.34	12.23
Wind physics and meteorology	0.12	1.73
Logistics, turbine installation, maintenance and operation	23.00	12.88
Environmental aspects of wind power and ecological accompanying research	1.43	2.33
Other	7.29	7.82

Table 2: Actual outlays in the Field of Energy Conversion

Funding area	Actual outlays in million euros 2012	2013
Bioenergy (incl. other programs)	**33.51** (41.23)	**36.70** (42.78)
Production – farming	6.91	6.31
Production – cultivation	4.43	5.25
Conversion – biogas	2.78	0.94
Conversion – biofuels	4.11	6.12
Conversion – solid biomass	4.61	4.87
Horizontal – environmental impact	1.03	1.33
Horizontal – international	0.01	0.02
Horizontal – economy	0.00	0.00
Basic research (incl. other programs)	8.81 (16.53)	9.99 (16.06)
Other	0.83	1.87
Deep geothermal energy	**20.82**	**17.10**
Surveying and exploration	8.39	7.28
Hot water and steam deposits	4.36	4.97
Hot dry rock	3.69	0.91
Other	4.37	3.94
Power plant technology and CCS technologies (incl. other programs)	**27.54** (28.58)	**31.62** (35.09)
Advanced power plant systems	10.76	7.45
Component development	9.18	16.52
Coal gasification	2.39	1.54
Basic research (incl. other programs)	4.54 (5.58)	3.79 (7.27)
Other	0.68	2.32
Fuel Cells and hydrogen	**19.47**	**24.88**
NT-PEM	6.15	6.68
HT-PEMFC	1.30	1.75
MCFC	0.55	0.14
SOFC	7.40	11.10
DMFC	0.56	0.34
Hydrogen storage	1.98	3.16
Hydrogen production	0.83	0.63
Basic research	0.71	1.08

Table 2: Actual outlays in the Field of Energy Conversion

Funding area	Actual outlays in million euros 2012	2013
Solar thermal power plants	**5.71**	**8.43**
Parabolic	1.93	2.25
Tower	2.01	2.50
Fresnel	0.68	0.63
Storage	0.30	1.79
Other	0.78	1.26
Hydroelectric and marine power	**0.98**	**1.25**
Total (incl. other programs)	**213.52** (240.89)	**236.14** (263.26)

Table 3: Actual outlays in the field of Energy Distribution and Energy Use

Funding area	Actual outlays in million euros 2012	2013
Energy storage (incl. other programs)	**31.02** (38.90)	**59.30** (61.46)
Electrochemical storage	14.48	23.87
High temperature storage	0.47	0.47
Mechanical storage	1.19	3.26
Electrical storage	0.74	0.28
Low temperature storage	1.53	3.37
Basic research (incl. other programs)	10.20 (18.08)	19.37 (21.53)
Other	2.41	8.67
Power Grids	**17.40**	**30.95**
Components	1.93	10.15
Grid planning	0.78	2.51
Management	9.74	12.62
System studies	0.06	1.68
Other	1.84	3.50
Basic research	3.06	0.49

Table 3: Actual outlays in the field of Energy Distribution and Energy Use

Funding area	**Actual outlays in million euros**	
	2012	**2013**
Energy Efficiency in Buildings and Cities	**45.23**	**56.91**
EnOB – Solar–optimised building	19.65	25.50
EnEff:Stadt – Supply concepts	7.85	9.69
EnEff:Stadt – District heating	2.50	3.53
EnEff:Stadt – Combined heat and power	2.93	4.61
Low–temperature Solar Thermal Energy	4.90	6.47
Solar cooling	1.73	1.21
Basic research	3.63	4.49
Other	2.04	1.40
Energy efficiency in the industrial, commerce, trade and services	**29.93**	**36.23**
Mechanical, electrical and precision engineering, automobile manufacturing, optics, metal goods	10.90	14.97
Iron and steel industry	2.42	1.54
Mining and processing of stone and earth, fine ceramics, glass	2.05	2.41
Heat pumping, refrigerants	1.28	2.99
Industrial furnaces	1.19	0.83
Mechanical and thermal separation methods	0.39	1.57
Chemical industry, manufacturing of plastic and rubber products	1.52	2.79
Non-ferrous metal industry	0.44	0.56
Heat exchangers	2.11	1.82
Solar process heat	0.21	0.15
Other	7.42	6.59
Total (incl. other programs)	**123.57** (131.45)	**183.39** (185.54)

Table 4: Actual outlays in the Cross-sector Energy Research

Funding area	Actual outlays in million euros 2012	2013
Horizontal Issues and System Analysis	**8.60**	**11.70**
System analysis	1.57	2.38
Information dissemination	2.49	3.27
Horizontal Issues	4.10	5.38
Other	0.44	0.66
Socio-ecological research (incl. other programs)	**0.00** (0.00)	**1.18** (3.08)
Project-related fusion research	**2.58**	**6.29**
Other BMBF project funding (incl. other programs)	**7.11** (7.11)	**2.35** (3.23)
Total (incl. other programs)	**18.29** (18.29)	**21.52** (24.30)

Table 5: Actual outlays in the field of Nuclear Safety Research

Funding area	Actual outlays in million euros 2012	2013
Nuclear Waste Final Storage and Disposal Research	**12.01**	**11.89**
Storage research	9.84	9.34
Nuclear material monitoring	0.18	0.15
Partitioning and transmutation	0.25	0.23
Funding for young researchers	1.74	2.17
Reactor Safety Research	**24.38**	**23.43**
Safety of nuclear facility components	5.28	4.01
Plant behaviour and accident sequences	11.25	12.09
Horizontal tasks and other	5.08	5.72
Funding for young researchers	2.77	1.62
Radiation research – Funding for young researchers	**4.91**	**4.95**
Total	**41.30**	**40.27**

Table 6: Actual outlays for Institutional Energy Research*

Funding area	Actual outlays in million euros	
	2012	2013
Efficient energy conversion and use	67.34	70.34
Renewable energy	50.75	53.74
Nuclear safety research	31.64	32.22
Nuclear fusion	130.52	132.43
Technology, innovation and society	9.92	10.05
Total	**290.17**	**298.78**

* The figures for 2013 are provisional.

5.2 Funding for Energy Research from German States

The figures for 2013 are not available yet.

Table 7: Actual outlays from German States per State

State	Actual outlays in million euros				
	2008	2009	2010	2011	2012
Baden-Württemberg	11.54	26.83	15.10	23.12	24.77
Bavaria	16.67	14.14	22.64	32.28	88.13
Berlin	3.87	15.53	4.73	2.10	3.03
Brandenburg	11.34	4.65	4.37	5.81	4.03
Bremen	2.71	2.42	2.78	3.61	2.71
Hamburg	1.15	1.56	0.61	1.27	2.01
Hesse	7.02	5.77	9.10	8.12	12.57
Mecklenburg-Western Pomerania	0.00	1.64	5.68	3.99	8.76
Lower Saxony	15.74	24.60	26.36	30.53	32.82
North Rhine-Westphalia	31.52	22.68	31.80	26.55	37.27
Rhineland-Palatinate	2.43	2.76	2.40	2.79	2.10
Saarland	0.95	1.17	0.51	1.12	0.87
Saxony	14.18	29.26	17.42	23.60	24.88
Saxony-Anhalt	2.51	3.83	7.81	6.04	3.43
Schleswig-Holstein	4.12	3.54	3.10	2.08	1.83
Thuringia	3.10	0.78	2.68	1.36	3.55
Total	**128.87**	**161.14**	**157.11**	**174.39**	**252.78**

Table 8: Actual outlays from German States per Sector

Sector	Actual outlays in million euros				
	2008	2009	2010	2011	2012
Biomass	21.48	7.79	15.90	18.73	18.71
Fuel cells and hydrogen	9.47	10.86	15.14	8.11	5.40
Carbon storage	0.00	0.11	0.24	0.07	0.21
Energy saving	24.86	32.19	23.74	31.66	51.35
General energy research	22.21	40.20	12.97	14.96	21.01
Energy systems, modelling	4.48	12.02	7.87	2.46	5.37
Renewables general	14.45	13.38	18.09	28.28	35.83
Geothermal	1.27	8.41	8.86	11.27	12.52
Power plant technology / CCS	5.09	3.87	4.84	6.09	11.35
Photovoltaics	18.12	22.17	19.62	20.84	26.95
Wind Power	5.89	6.12	8.26	11.61	14.48
E-mobility / power storage / grids	1.55	4.02	21.58	20.31	49.61
Total	**128.87**	**161.14**	**157.11**	**174.39**	**252.78**

5.3 Funding under the European Union Research Framework Programme

In contrast to national statistics, the funding totals, which have been recommended after evaluation by the European Commission, for successful, i.e. fundable proposals will be displayed in the European Union's research funding statistics.

Table 9: Distribution of Subsidies from the European Union in the field of non-nuclear energy research by country*

Country	in million euros
	2007 – 2013
Germany	282
Spain	241
Italy	189
France	173
The Netherlands	142
United Kingdom	128
Denmark	110

Table 9: Distribution of Subsidies from the European Union in the field of non-nuclear energy research by country*

Country	in million euros 2007 – 2013
Sweden	92
Belgium	89
Finland	64
Austria	60
Greece	38
Portugal	25
Ireland	21
Poland	13
Hungary	10
Slovakia	7
Lithuania	7
Czech Republic	6
Slovenia	5
Luxembourg	3
Cyprus	3
Bulgaria	3
Romania	2
Latvia	2
Estonia	1
Malta	0
Total	**1,716**

* The information is based on the funding totals, which have been recommended after evaluation by the European Commission, for successful, i.e. fundable proposals. ERA-Net-Calls (2007, 2011, 2012, 2013) and Ocean-Calls (2010, 2011, 2013) were not included in the analysis for reasons of comparability. The German participation to these calls was low.

Table 10: Distribution of Subsidies by the European Union in the field of non-nuclear energy research by year*

Countries	in million euros						
	2007	2008	2009	2010	2011	2012	2013
Total	**219**	**214**	**197**	**235**	**251**	**277**	**322**

* The information is based on the funding totals, which have been recommended after evaluation by the European Commission, for successful, ie fundable proposals. ERA-Net-Calls (2007, 2011, 2012, 2013) and Ocean-Calls (2010, 2011, 2013) were not included in the analysis for reasons of comparability. The German participation to these calls was low.

Table 11: Distribution of Subsidies by the European Union for Germany according to the activities in the field of non-nuclear energy research*

Funding area	in million euros 7th FP
Hydrogen and fuel cells (2007 only)	5.93
Renewable electricity generation	103.43
Renewable fuel production	49.48
Renewables for heating and cooling	10.70
CO_2 capture and storage technologies for zero emission power generation sound	18.45
Clean coal technologies	4.61
Cross cutting actions	2.03
Smart energy networks	40.54
Energy efficiency and savings	28.99
Knowledge for energy policy making	1.75
Horizontal program actions	16.39
Total	**282.31**

* The information is based on the funding totals, which have been recommended after evaluation by the European Commission, for successful, i.e. fundable proposals. ERA-Net-Calls (2007, 2011, 2012, 2013) and Ocean-Calls (2010, 2011, 2013) were not included in the analysis for reasons of comparability. The German participation to these calls was low.

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